

# PROGRAMMING ASSIGNMENT 2

## **PROBLEM:**

The problem is to sort large datasets of sizes varying from 1 GB to 100 GB or 1 TB in a standalone and distributed environment. We compare the performance of sorting algorithms for data executed in different frameworks namely Hadoop and Spark with a sorting algorithm written to sort the data from memory(shared memory).

## **Solution:**

The **shared memory** sorting is done using external merge sort algorithm. Here the dataset is divided into chunks of fixed size and each chunk is kept in memory, sorted by first 10 bytes of each line which is the key and merged to obtain the sorted file. The program has been executed in Linux environment (Ubuntu) .

To generate the dataset, a utility called **gensort** is used. After sorting **valsort** is used to validate that the records have been sorted.

Next we use the **Hadoop framework** with Map Reduce to sort the dataset. Here in the map phase, we configure the mapper such that first ten bytes of each row is the key. The result of the map phase is a sorted collection of keys in ascending order (lexicographical order) and hence the reduce phase does no operation as such. The disadvantage of this framework is that the intermediate data of the runs is not stored. We run both standalone and cluster with master slave set up to sort the dataset.

To overcome the shortcoming of Hadoop, **Spark** framework is used. It stores the data between shuffles(intermediate runs) and is hence faster than hadoop.

## **Run time environment settings:**

Since the intermediate shuffle data needs to be stored, we need to configure the instances to contain more memory. This is done by raiding the external memory using raid0.

## **Installation:**

### **Shared Memory:**

The programming is done in Java 1.7 using Eclipse in Ubuntu/Linux environment. Gensort is used to generate the input dataset and valsort is used to validate the sorted output.

### **Hadoop:**

Code:

Java 1.7 in Eclipse with ANT builder to build the jar.

Infrastructure:

Hadoop 2.7.2 is used on Ubuntu c3.large instance. Amazon Web Services EC2 service is used to create the clusters and standalone nodes. Spot instances are used by bidding on them as and when required. The changes required in the config files are as follows:

1) Add the HADOOP\_HOME, PATH, CONF, JAVA\_HOME to .bashrc script.

2) Changes to files under hadoop/etc/hadoop folder:

*core-site.xml* – Add public DNS of the node

**Change for 16 node cluster:** Add hadoop temporary directory property and provide a path in memory which is free.

*slaves* – Add own public DNS if it is slave else add IP of master node followed by public DNS of all slaves

*masters* – Add public DNS of master if it is master node else blank

*hdfs-site.xml* – Check for replication factor = 1

*mapred-site.xml* – Include the public DNS of the master node

**Change for 16 node cluster:** Specify number of mappers and reducers and provide the temporary directory for mapred.

*yarn-site.xml* – Add public DNS of the master node.

**Change for 16 node cluster:** disable disk health check property – “yarn.nodemanager.disk-health-checker.enable” must be set to value false

3) Format the namenode

In hadoop/bin - ./hdfs namenode -format

4) Start the datanodes

Configure password less ssh for the slaves from master using eval and ssh-add command.

In hadoop/sbin - ./start-dfs.sh

5) Start the yarn resource managers

In hadoop/sbin - ./stop-dfs.sh

6) Generate the dataset using gensort and upload it to hdfs using command:

hadoop fs -put “source path” “path on hdfs”

7) Create a jar file of the map reduce program written and save it in the instance. Run the map reduce job using the following command:

hadoop jar “jar location” “input path” “output path”

Note: Input and output path will be in HDFS.

Repeat the same procedure for creating multi node cluster.

#### **MASTER NODE:**

A master node is the node that is in control of all the resources in the cluster and keeps track of the workload of each slave/worker node in the cluster. It is responsible to divide the work and co-ordinate among all the workers.

## **SLAVE NODE:**

A slave node is a worker node in the cluster which works on a part of the task assigned by the master node in the distributed environment.

***Why do we need to set unique available ports to those configuration files on a shared environment? What errors or side-effects will show if we use same port number for each user?***

We need to set unique port numbers as the parameters set in the configuration files include the directory path. The public DNS of the nodes along with the port numbers are thus required to ensure that the work done for one user does not interfere with others in a distributed environment.

***How can we change the number of mappers and reducers from the configuration file?***

The number of mapper and reducers can be configured using the following property in mapred-site.xml

```
<property>
<name>mapreduce.job.running.map.limit</name>
<value>4</value>
</property>
<property>
<name>mapreduce.job.running.reduce.limit</name>
<value>2</value>
</property>
```

But the number of mappers can only be suggested to Hadoop whereas the number of reducers can be provided by the user and it will be considered.

## **Challenges:**

- 1) The spot instances are taken away within an hour of operation sometimes, which leads to lot of rework.
- 2) There was always an issue of “no space left on the device” due to the volume of temp data being written. It required a considerable amount of external memory to be raided and configured as the directory to be written into in order to proceed with the execution. Else the application got stuck waiting for the resources to be freed or eventually failed.

## **Spark:**

Spark 1.6.0 version pre-built for Hadoop 2.6 is used.

Steps to be followed to run the program are:

- 1) Set the access key and security key generated in AWS console and Run a script to create the spark master and slave nodes

```
./spark-ec2 -k spark -i /home/ubuntu/spark.pem -s 16 -t d2.xlarge -r us-east-1 --spot-price=0.22
```

*launch spark\_cluster\_multi*

2) Raid memory using EBS volumes as intermediate values are stored during the runs and they occupy a lot of memory.

3) Scala interpreter prompt is used to run the code.

Type your code in the prompt and execute.

### **Challenges:**

The memory issue due to shuffle data being stored, demands that external disk of large size be allocated to the node.

Sometimes, the execution would fail in the last stage due to this.

## Results:

### Shared Memory:

1 GB: 1 thread

```
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64
root@ip-172-31-15-130:/home/ubuntu/gensort-linux-1.5/64# exit
exit
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/dataset_new
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ cd
ubuntu@ip-172-31-15-130:~$ ls -l
total 517164
drwxrwxr-x  2 ubuntu ubuntu      4096 Mar 17 02:53 dataset_output
drwxrwxr-x  4 ubuntu ubuntu      4096 Mar 16 23:49 gensort-linux-1.5
drwxr-xr-x 10 ubuntu ubuntu     4096 Mar  7 16:04 hadoop
drwxr-xr-x 15 ubuntu ubuntu     4096 Jan 26 00:07 hadoop-2.7.2-src
-rw-rw-r--  1 ubuntu ubuntu 18290860 Mar  7 05:39 hadoop-2.7.2-src.tar.gz
-rw-rw-r--  1 ubuntu ubuntu 212046774 Mar  7 06:09 hadoop-2.7.2.tar.gz
-rw-----  1 ubuntu ubuntu    1696 Mar  7 05:21 Hadoop.pem
-rw-rw-r--  1 ubuntu ubuntu   1018 Mar 27 21:19 MergeSortEightThreads.java
-rw-rw-r--  1 ubuntu ubuntu   1086 Mar 27 21:19 MergeSortFourThreads.java
-rw-rw-r--  1 ubuntu ubuntu   5045 Mar 27 21:19 MergeSortThread.java
-rw-r----- 1 ubuntu ubuntu 10000000 Mar 17 02:27 part-r-00000
-rw-rw-r--  1 ubuntu ubuntu    9008 Mar 27 21:19 SortingExternal.java
-rw-rw-r--  1 ubuntu ubuntu   2712 Mar 17 02:51 sort.jar
drwxr-xr-x 12 ubuntu ubuntu     4096 Mar 16 03:02 spark-1.6.0-bin-hadoop2.6
-rw-rw-r--  1 ubuntu ubuntu 289160984 Mar  7 16:10 spark-1.6.0-bin-hadoop2.6.tgz
-rw-----  1 ubuntu ubuntu    1692 Mar  7 16:27 spark.pem
drwxrwxr-x  2 ubuntu ubuntu     4096 Mar 17 01:19 terasort_out
-rw-rw-r--  1 ubuntu ubuntu     105 Mar 14 16:38 words
ubuntu@ip-172-31-15-130:~$ javac SortingExternal.java MergeSortEightThreads.java MergeSortFourThreads.java MergeSortThread.java
ubuntu@ip-172-31-15-130:~$ java SortingExternal
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
The time taken is 305860 ns
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem1gb_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem1gb_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem1gb_output
unix2dos: converting file sharedmem1gb_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem1gb_output
*Records: 20
Checksum: a77de415
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

## 2 Threads:

```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64
total 197255928
drwx----- 3 ubuntu ubuntu        4096 Mar 27 16:22 datanode
-rw-rw-r-x 1 ubuntu ubuntu 100000000000 Mar 27 16:53 dataset_hgb
-rw-rw-r-x 1 ubuntu ubuntu 1000000000 Mar 27 20:16 dataset_new
-rw-rw-r-- 1 ubuntu ubuntu    989998218 Mar 27 20:24 dataset_output
drwx----- 2 root  root       16384 Mar 27 14:53 lost+found
drwxrwxr-x 3 ubuntu ubuntu        4096 Mar 27 16:22 namenode
drwxr-xr-x 5 ubuntu ubuntu        4096 Mar 27 16:24 nm-local-dir
-rw-r--r-- 1 ubuntu ubuntu 49999526400 Mar 27 19:53 part-r-00000
-rw-r--r-- 1 ubuntu ubuntu 50000473600 Mar 27 20:08 part-r-00001
ubuntu@ip-172-31-2-61:~$ head /mnt/raid/dataset_output >> sharedmem1gb_ouput
ubuntu@ip-172-31-2-61:~$ tail /mnt/raid/dataset_output >> sharedmem1gb_ouput
ubuntu@ip-172-31-2-61:~$ ls -l
total 100
drwxrwxr-x 4 ubuntu ubuntu 4096 Mar 16 23:49 gensort-linux-1.5
drwxr-xr-x 10 ubuntu ubuntu 4096 Mar 7 16:04 hadoop
-rw----- 1 ubuntu ubuntu 1696 Mar 7 05:21 Hadoop.pem
-rw-rw-r-- 1 ubuntu ubuntu 1000 Mar 26 21:47 hadoop_tengb_firstten_output
-rw-rw-r-- 1 ubuntu ubuntu 1000 Mar 26 21:47 hadoop_tengb_lastten_output
-rw-rw-r-- 1 ubuntu ubuntu 1018 Mar 27 20:17 MergeSortEightThreads.java
-rw-rw-r-- 1 ubuntu ubuntu 1086 Mar 27 20:17 MergeSortFourThreads.java
-rw-rw-r-- 1 ubuntu ubuntu 5045 Mar 27 20:17 MergeSortThread.java
drwxrwxr-x 7 ubuntu ubuntu 4096 Mar 27 15:41 pssh-2.3.1
-rw-rw-r-- 1 ubuntu ubuntu 23427 Mar 27 05:13 pssh-2.3.1.tar.gz
-rw-rw-r-- 1 ubuntu ubuntu 1980 Mar 27 20:31 sharedmem1gb_ouput
-rw-rw-r-- 1 ubuntu ubuntu 4369 Mar 27 20:19 SortingExternal.class
-rw-rw-r-- 1 ubuntu ubuntu 9008 Mar 27 20:17 SortingExternal.java
-rw-rw-r-- 1 ubuntu ubuntu 2710 Mar 27 16:25 sort.jar
drwxr-xr-x 12 ubuntu ubuntu 4096 Mar 16 03:02 spark-1.6.0-bin-hadoop2.6
-r----- 1 ubuntu ubuntu 1692 Mar 7 16:27 spark.pem
ubuntu@ip-172-31-2-61:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/sharedmem1gb_ouput
sump pump fatal error: pfunc_get_rec: partial record of 80 bytes found at end of input
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ unix2dos /home/ubuntu/sharedmem1gb_ouput
unix2dos: converting file /home/ubuntu/sharedmem1gb_ouput to DOS format ...
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/sharedmem1gb_ouput
Records: 20
Checksum: a77dea415
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$
```

## 4 threads:

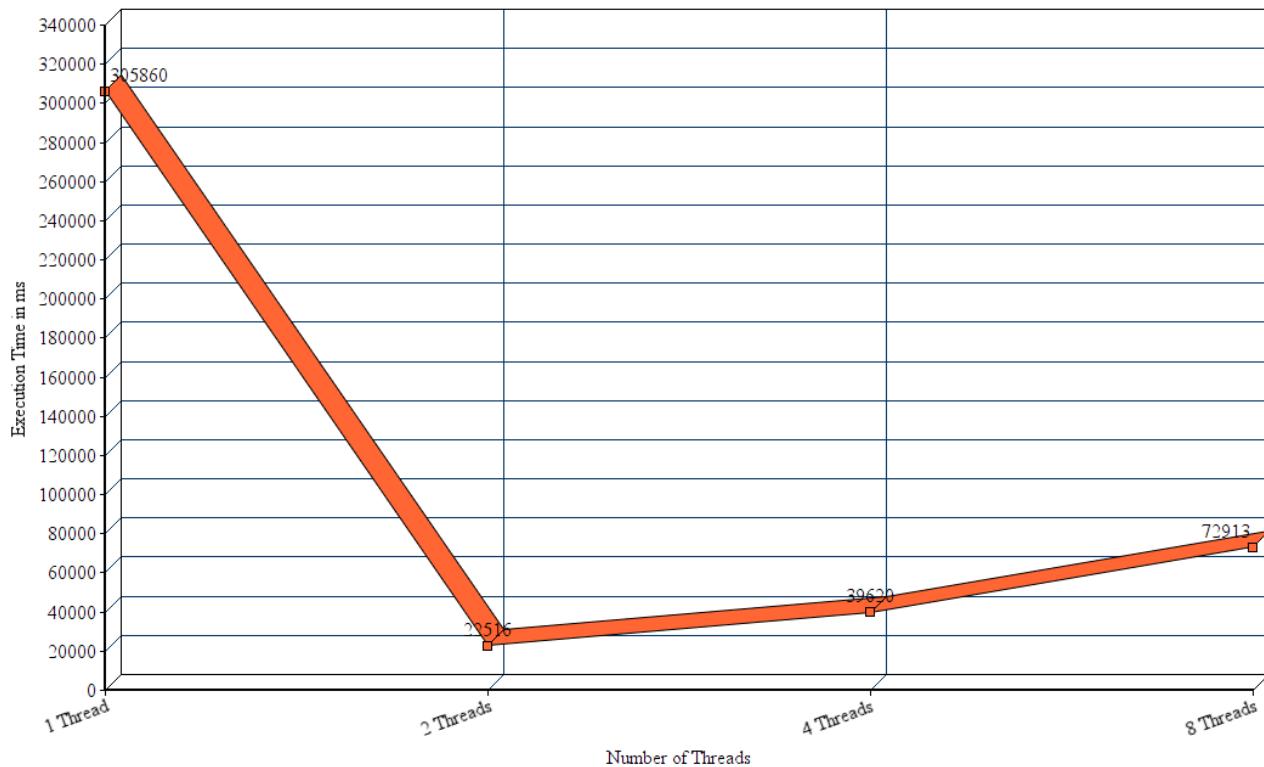
```
ubuntu@ip-172-31-15-130: ~/gensort-linux-1.5/64
The thread Thread-19 is running
Sorting start time for 4 threads--
The thread Thread-20 is running
The thread Thread-21 is running
The thread Thread-22 is running
The thread Thread-23 is running
Sorting start time for 4 threads--
The thread Thread-24 is running
The thread Thread-25 is running
The thread Thread-26 is running
The thread Thread-27 is running
Sorting start time for 4 threads--
The thread Thread-28 is running
The thread Thread-29 is running
The thread Thread-30 is running
The thread Thread-31 is running
Sorting start time for 4 threads--
The thread Thread-32 is running
The thread Thread-33 is running
The thread Thread-34 is running
The thread Thread-35 is running
Sorting start time for 4 threads--
The thread Thread-36 is running
The thread Thread-37 is running
The thread Thread-38 is running
The thread Thread-39 is running
Sorting total time in ms-->39620
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem1gb_4threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem1gb_4threads_output
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ unix2dos /home/ubuntu/sharedmem1gb_4threads_output
unix2dos: converting file /home/ubuntu/sharedmem1gb_4threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/sharedmem1gb_4threads_output
Records: 20
Checksum: a77dea415
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

8 threads:

```
ubuntu@ip-172-31-15-130:~/gnsort-linux-1.5/64
The thread Thread-56 is running
The thread Thread-57 is running
The thread Thread-58 is running
The thread Thread-59 is running
The thread Thread-60 is running
The thread Thread-61 is running
The thread Thread-62 is running
The thread Thread-63 is running
Sorting start time for 8 threads--
The thread Thread-64 is running
The thread Thread-65 is running
The thread Thread-66 is running
The thread Thread-67 is running
The thread Thread-68 is running
The thread Thread-69 is running
The thread Thread-70 is running
The thread Thread-71 is running
Sorting start time for 8 threads--
The thread Thread-72 is running
The thread Thread-73 is running
The thread Thread-74 is running
The thread Thread-75 is running
The thread Thread-76 is running
The thread Thread-77 is running
The thread Thread-78 is running
The thread Thread-79 is running
Sorting total time in ms-->72913
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem1gb_8threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem1gb_8threads_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem1gb_8threads_output
unix2dos: converting file sharedmem1gb_8threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gnsort-linux-1.5/64
ubuntu@ip-172-31-15-130:~/gnsort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem1gb_8threads_output
Records: 20
Checksum: a77dea415
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gnsort-linux-1.5/64$
```

## Performance: Execution Time in ms

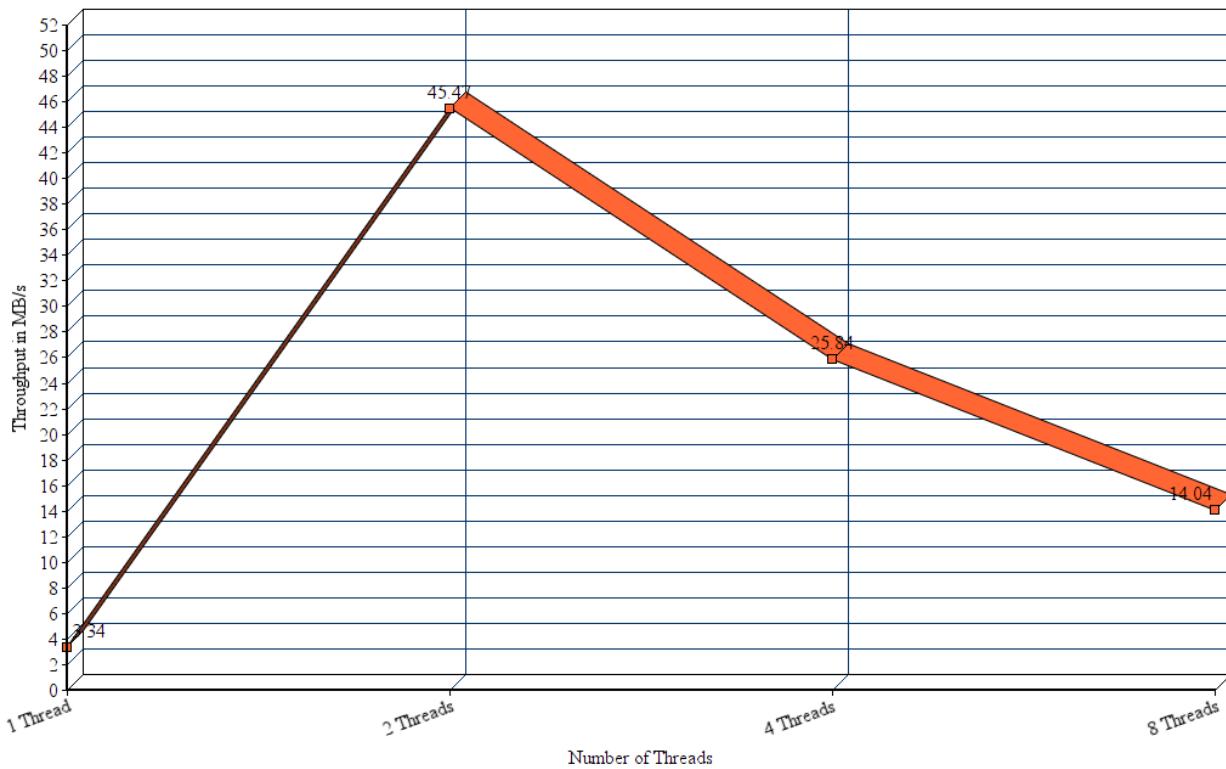
Shared Memory 1 GB



The execution time is least and optimal when the number of threads is equal to 2. This is because more number of threads does not necessarily mean better performance as we have only 2 cores in the c3.large instance. It may lead to more overhead for thread synchronization and hence may take more time to execute.

## Throughput in MB/s:

Shared Memory 1 GB Throughput



The highest throughput is when the execution time is least. This is the case when number of threads is equal to 2. This is the optimal number for best performance of shared memory on c3.large instance.

## 10 GB: 1 Thread

```
ubuntu@ip-172-31-15-130: ~/gensort-linux-1.5/64
The thread Thread-73 is running
The thread Thread-74 is running
The thread Thread-75 is running
The thread Thread-76 is running
The thread Thread-77 is running
The thread Thread-78 is running
The thread Thread-79 is running
Sorting total time in ms-->72913
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem1gb_8threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem1gb_8threads_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem1gb_8threads_output
unix2dos: converting file sharedmem1gb_8threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem1gb_8threads_output
Records: 20
Checksum: a77dea415
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ rm /mnt/raid/dataset_output
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ rm /mnt/raid/dataset_new
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./gensort -a 100000000 /mnt/raid/dataset_new
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ cd ..
ubuntu@ip-172-31-15-130:~$ java SortingExternal
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
The time taken is 466061 ms
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem10gb_1threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem10gb_1threads_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem10gb_1threads_output
unix2dos: converting file sharedmem10gb_1threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem10gb_1threads_output
Records: 20
Checksum: a8261f3d1
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

## 2 threads:

```
ubuntu@ip-172-31-15-130: ~/gensort-linux-1.5/64
The thread Thread-3 is running
Sorting start time for 2 threads--
The thread Thread-4 is running
The thread Thread-5 is running
Sorting start time for 2 threads--
The thread Thread-6 is running
The thread Thread-7 is running
Sorting start time for 2 threads--
The thread Thread-8 is running
The thread Thread-9 is running
Sorting start time for 2 threads--
The thread Thread-10 is running
The thread Thread-11 is running
Sorting start time for 2 threads--
The thread Thread-12 is running
The thread Thread-13 is running
Sorting start time for 2 threads--
The thread Thread-14 is running
The thread Thread-15 is running
Sorting start time for 2 threads--
The thread Thread-16 is running
The thread Thread-17 is running
Sorting start time for 2 threads--
The thread Thread-18 is running
The thread Thread-19 is running
Sorting total time in ms-->34805
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem10gb_2threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem10gb_2threads_output
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5$ cd 64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ unix2dos /home/ubuntu/sharedmem10gb_2threads_output
unix2dos: converting file /home/ubuntu/sharedmem10gb_2threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem10gb_2threads_output
Records: 20
Checksum: a8261f3d1
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

## 4 threads

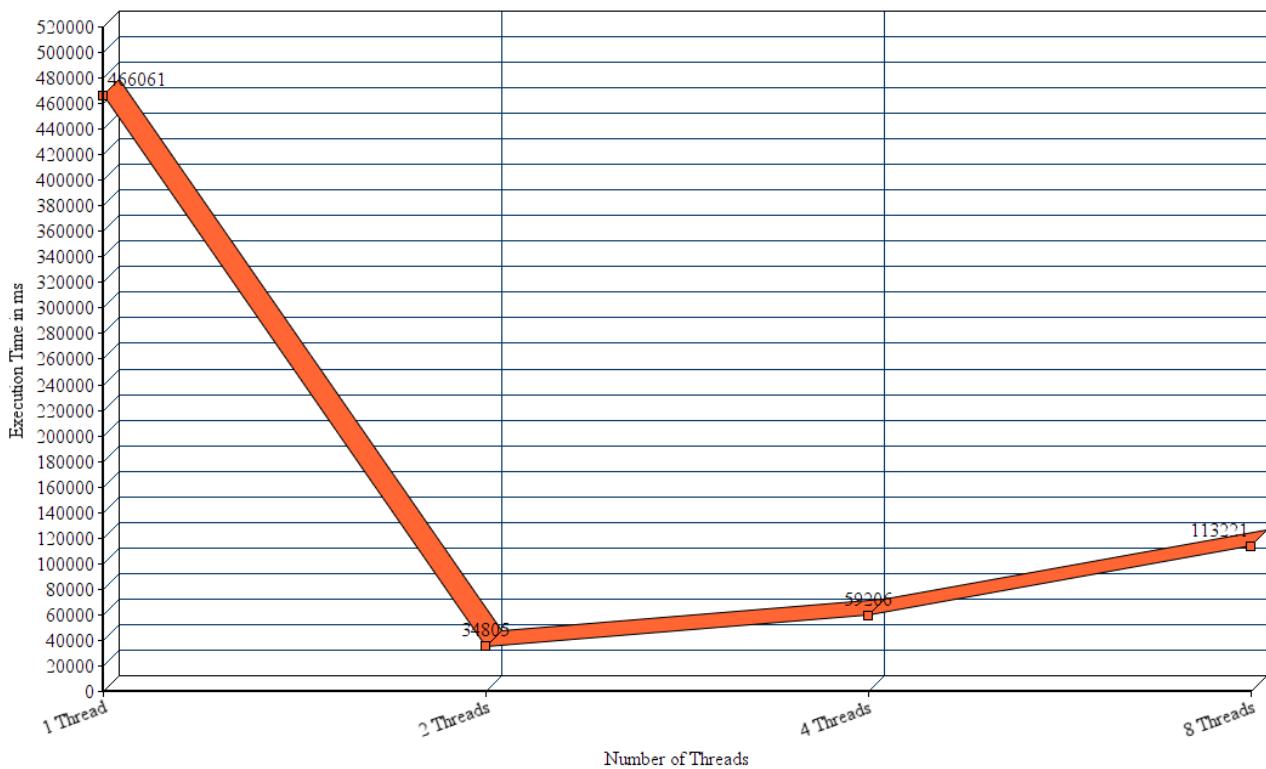
```
ubuntu@ip-172-31-15-130: ~/gensort-linux-1.5/64
Sorting start time for 4 threads--
The thread Thread-20 is running
The thread Thread-21 is running
The thread Thread-22 is running
The thread Thread-23 is running
Sorting start time for 4 threads--
The thread Thread-24 is running
The thread Thread-25 is running
The thread Thread-26 is running
The thread Thread-27 is running
Sorting start time for 4 threads--
The thread Thread-28 is running
The thread Thread-29 is running
The thread Thread-30 is running
The thread Thread-31 is running
Sorting start time for 4 threads--
The thread Thread-32 is running
The thread Thread-33 is running
The thread Thread-34 is running
The thread Thread-35 is running
Sorting start time for 4 threads--
The thread Thread-36 is running
The thread Thread-37 is running
The thread Thread-38 is running
The thread Thread-39 is running
Sorting total time in ms-->59206
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem10gb_4threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem10gb_4threads_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem10gb_4threads_output
unix2dos: converting file sharedmem10gb_4threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5$ cd 64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem10gb_4threads_output
Records: 20
Checksum: a8261f3d1
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

## 8 threads:

```
ubuntu@ip-172-31-15-130: ~/gensort-linux-1.5/64
The thread Thread-58 is running
The thread Thread-59 is running
The thread Thread-60 is running
The thread Thread-61 is running
The thread Thread-62 is running
The thread Thread-63 is running
Sorting start time for 8 threads--
The thread Thread-64 is running
The thread Thread-65 is running
The thread Thread-66 is running
The thread Thread-67 is running
The thread Thread-68 is running
The thread Thread-69 is running
The thread Thread-70 is running
The thread Thread-71 is running
Sorting start time for 8 threads--
The thread Thread-72 is running
The thread Thread-73 is running
The thread Thread-74 is running
The thread Thread-75 is running
The thread Thread-76 is running
The thread Thread-77 is running
The thread Thread-78 is running
The thread Thread-79 is running
Sorting total time in ms-->113221
Merging divisions The file size is 10
Length of readers is 10
The size of data array is 10
ubuntu@ip-172-31-15-130:~$ ^C
ubuntu@ip-172-31-15-130:~$ head /mnt/raid/dataset_output >> sharedmem10gb_8threads_output
ubuntu@ip-172-31-15-130:~$ tail /mnt/raid/dataset_output >> sharedmem10gb_8threads_output
ubuntu@ip-172-31-15-130:~$ unix2dos sharedmem10gb_8threads_output
unix2dos: converting file sharedmem10gb_8threads_output to DOS format ...
ubuntu@ip-172-31-15-130:~$ cd gensort-linux-1.5/
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5$ cd 64
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$ ./valsort /home/ubuntu/sharedmem10gb_8threads_output
Records: 20
Checksum: a8261f3d1
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-15-130:~/gensort-linux-1.5/64$
```

## Performance: Execution Time (ms)

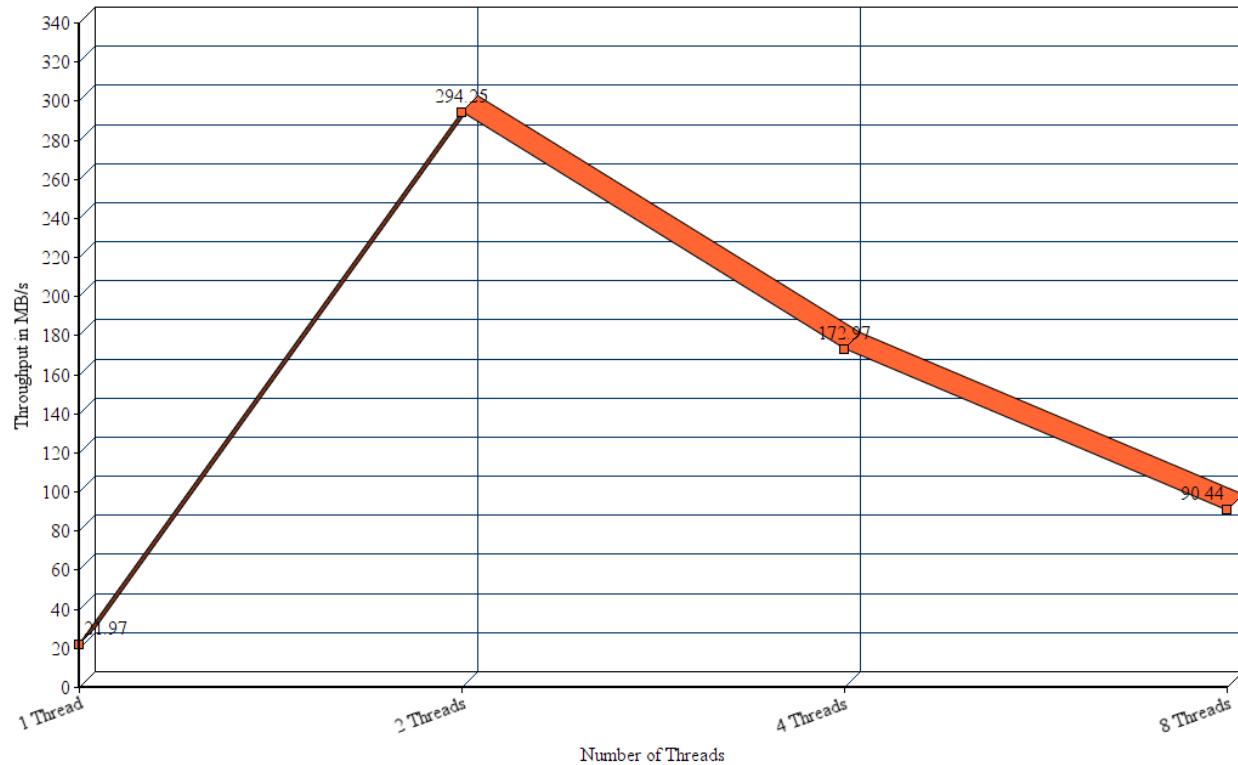
Shared Memory 10 GB



The time taken for execution is more than the time taken for 1 GB dataset but it follows the same trend. It is optimal at number of threads equal to 2 for c3.large instance which contains 2 virtual cores.

## Throughput in MB/s:

Shared Memory Throughput 10 GB



The throughput is highest at 2 threads for which the execution time is least. This is the best case for c3.large instance with 2 virtual cores.

## Hadoop:

### Single Node: 1 GB

```
ubuntu@ip-172-31-60-26: ~/gensort-linux-1.5/64
drwxrwxr-x 2 ubuntu ubuntu 4096 Mar 17 01:19 terasort_out
-rw-r--r-- 1 ubuntu ubuntu 105 Mar 14 16:38 words
ubuntu@ip-172-31-60-26:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/terasort_data
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ rm /mnt/raid/terasort_data
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/dataset_gb
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ hadoop fs -put /mnt/raid/dataset_gb hdfs:/
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ hadoop fs -ls hdfs:
Found 1 items
-rw-r--r-- 1 ubuntu supergroup 1000000000 2016-03-19 01:40 hdfs://dataset_gb
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ hadoop jar /home/ubuntu/sort.jar hdfs://dataset_gb hdfs:///dataset_output_gb
16/03/19 01:41:41 INFO Configuration.deprecation: session.id is deprecated. Instead, use dfs.metrics.session-id
16/03/19 01:41:41 INFO jvm.JvmMetrics: Initializing JVM Metrics with processName=JobTracker, sessionId=
16/03/19 01:41:41 INFO input.FileInputFormat: Total input paths to process : 1
16/03/19 01:41:41 INFO mapreduce.JobSubmitter: number of splits:8
16/03/19 01:41:43 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local1194024410_0001
16/03/19 01:41:43 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
16/03/19 01:41:43 INFO mapreduce.Job: Running job: job_local1194024410_0001
16/03/19 01:41:43 INFO mapred.LocalJobRunner: OutputCommitter set in config null
16/03/19 01:41:43 INFO mapred.LocalJobRunner: File Output Committer Algorithm version is 1
16/03/19 01:41:43 INFO mapred.LocalJobRunner: OutputCommitter is org.apache.hadoop.mapreduce.lib.output.FileOutputCommitter
16/03/19 01:41:43 INFO mapred.LocalJobRunner: Waiting for map tasks
16/03/19 01:41:43 INFO mapred.LocalJobRunner: Starting task: attempt_local1194024410_0001_m_000000_0
16/03/19 01:41:43 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 1
16/03/19 01:41:43 INFO mapred.Task: Using ResourceCalculatorProcessTree : [ ]
16/03/19 01:41:43 INFO mapred.MapTask: Processing split: hdfs://ec2-52-87-179-107.compute-1.amazonaws.com:8020/dataset_gb:0+134217728
16/03/19 01:41:43 INFO mapred.MapTask: (EQUATOR) @ kvi 26214396(104857584)
16/03/19 01:41:43 INFO mapred.MapTask: mapreduce.task.io.sort.mb: 100
16/03/19 01:41:43 INFO mapred.MapTask: soft limit at 83886080
16/03/19 01:41:43 INFO mapred.MapTask: bufstart = 0; bufvoid = 104857600
16/03/19 01:41:43 INFO mapred.MapTask: kvstart = 26214396; length = 6553600
16/03/19 01:41:43 INFO mapred.MapTask: Map output collector class = org.apache.hadoop.mapred.MapTask$MapOutputBuffer
16/03/19 01:41:44 INFO mapreduce.Job: Job job_local1194024410_0001 running in uber mode : false
16/03/19 01:41:44 INFO mapred.MapTask: map 0% reduce 0%
16/03/19 01:41:45 INFO mapred.MapTask: Spilling map output
16/03/19 01:41:45 INFO mapred.MapTask: bufstart = 0; bufend = 72315600; bufvoid = 104857600
16/03/19 01:41:45 INFO mapred.MapTask: kvstart = 26214396(104857584); kvend = 23321776(93287104); length = 2892621/6553600
16/03/19 01:41:45 INFO mapred.MapTask: (EQUATOR) 75208208 kvi 18802048(75208192)
16/03/19 01:41:47 INFO mapred.MapTask: Finished spill 0
16/03/19 01:41:47 INFO mapred.MapTask: (RESET) equator 75208208 kv 18802048(75208192) kvi 18078904(72315616)
```

```
ubuntu@ip-172-31-60-26: ~/gensort-linux-1.5/64
16/03/19 01:42:20 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13793548 bytes
16/03/19 01:42:20 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:20 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13713376 bytes
16/03/19 01:42:20 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:20 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13633816 bytes
16/03/19 01:42:21 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:21 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13681756 bytes
16/03/19 01:42:21 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:21 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13653094 bytes
16/03/19 01:42:21 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:21 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13698076 bytes
16/03/19 01:42:21 INFO mapred.Merger: Merging 2 sorted segments
16/03/19 01:42:21 INFO mapred.Merger: Down to the last merge-pass, with 2 segments left of total size: 13623718 bytes
16/03/19 01:42:21 INFO mapred.LocalJobRunner: map > sort >
16/03/19 01:42:21 INFO mapred.Task: Task:attempt_local1194024410_0001_m_000005_0 is done. And is in the process of committing
16/03/19 01:42:21 INFO mapred.LocalJobRunner: map > sort
16/03/19 01:42:21 INFO mapred.Task: Task 'attempt_local1194024410_0001_m_000005_0' done.
16/03/19 01:42:21 INFO mapred.LocalJobRunner: Finishing task: attempt_local1194024410_0001_m_000006_0
16/03/19 01:42:21 INFO mapred.LocalJobRunner: Starting task: attempt_local1194024410_0001_m_000006_0
16/03/19 01:42:21 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 1
16/03/19 01:42:21 INFO mapred.Task: Using ResourceCalculatorProcessTree : [ ]
16/03/19 01:42:21 INFO mapred.MapTask: Processing split: hdfs://ec2-52-87-179-107.compute-1.amazonaws.com:8020/dataset_gb:805306368+134217728
16/03/19 01:42:21 INFO mapred.MapTask: (EQUATOR) @ kvi 26214396(104857584)
16/03/19 01:42:21 INFO mapred.MapTask: mapreduce.task.io.sort.mb: 100
16/03/19 01:42:21 INFO mapred.MapTask: soft limit at 83886080
16/03/19 01:42:21 INFO mapred.MapTask: bufstart = 0; bufvoid = 104857600
16/03/19 01:42:21 INFO mapred.MapTask: kvstart = 26214396; length = 6553600
16/03/19 01:42:21 INFO mapred.MapTask: Map output collector class = org.apache.hadoop.mapred.MapTask$MapOutputBuffer
16/03/19 01:42:22 INFO mapreduce.Job: map 100% reduce 0%
16/03/19 01:42:22 INFO mapred.MapTask: Spilling map output
16/03/19 01:42:22 INFO mapred.MapTask: bufstart = 72315600; bufvoid = 104857600
16/03/19 01:42:22 INFO mapred.MapTask: kvstart = 26214396(104857584); kvend = 23321776(93287104); length = 2892621/6553600
16/03/19 01:42:22 INFO mapred.MapTask: (EQUATOR) 75208208 kvi 18802048(75208192)
16/03/19 01:42:24 INFO mapred.MapTask: Finished spill 0
16/03/19 01:42:24 INFO mapred.MapTask: (RESET) equator 75208208 kv 18802048(75208192) kvi 18078904(72315616)
16/03/19 01:42:24 INFO mapred.LocalJobRunner: Starting flush of map output
16/03/19 01:42:24 INFO mapred.MapTask: Spilling map output
16/03/19 01:42:24 INFO mapred.MapTask: bufstart = 75208208; bufend = 32252708; bufvoid = 104857600
16/03/19 01:42:24 INFO mapred.MapTask: kvstart = 18802048(75208192); kvend = 16325968(65303872); length = 2476081/6553600
```

```
ubuntu@ip-172-31-60-26: ~/gensort-linux-1.5/64
  File System Counters
    FILE: Number of bytes read=25602043916
    FILE: Number of bytes written=35043777136
    FILE: Number of read operations=0
    FILE: Number of large read operations=0
    FILE: Number of write operations=0
    HDFS: Number of bytes read=14758526464
    HDFS: Number of bytes written=5500537800
    HDFS: Number of read operations=451
    HDFS: Number of large read operations=0
    HDFS: Number of write operations=128
  Map-Reduce Framework
    Map input records=10000000
    Map output records=10000000
    Map output bytes=1000000000
    Map output materialized bytes=1020000480
    Input split bytes=1032
    Combine input records=10000000
    Combine output records=10000000
    Reduce input groups=10000000
    Reduce shuffle bytes=1020000480
    Reduce input records=10000000
    Reduce output records=10000000
    Spilled Records=29395241
    Shuffled Maps =80
    Failed Shuffles=0
    Merged Map outputs=80
    GC time elapsed (ns)=944
    Total committed heap usage (bytes)=8594128896
  Shuffle Errors
    BAD_ID=0
    CONNECTION=0
    IO_ERROR=0
    WRONG_LENGTH=0
    WRONG_MAP=0
    WRONG_REDUCE=0
  File Input Format Counters
    Bytes Read=1000028672
  File Output Format Counters
    Bytes Written=1000000000
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$
```

```
ubuntu@ip-172-31-60-26: ~/gensort-linux-1.5/64
  Combine input records=10000000
  Combine output records=10000000
  Reduce input groups=10000000
  Reduce shuffle bytes=1020000480
  Reduce input records=10000000
  Reduce output records=10000000
  Spilled Records=29395241
  Shuffled Maps =80
  Failed Shuffles=0
  Merged Map outputs=80
  GC time elapsed (ns)=944
  Total committed heap usage (bytes)=8594128896
  Shuffle Errors
    BAD_ID=0
    CONNECTION=0
    IO_ERROR=0
    WRONG_LENGTH=0
    WRONG_MAP=0
    WRONG_REDUCE=0
  File Input Format Counters
    Bytes Read=1000028672
  File Output Format Counters
    Bytes Written=1000000000
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ hadoop fs -ls hdfs://
Found 2 items
-rw-r--r--  1 ubuntu supergroup 1000000000 2016-03-19 01:42 hdfs://dataset_gb
drwxr-xr-x -  ubuntu supergroup          0 2016-03-19 01:42 hdfs://dataset_output_gb
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$ hadoop fs -ls hdfs://dataset_output_gb
Found 11 items
-rw-r--r--  1 ubuntu supergroup      0 2016-03-19 01:42 hdfs://dataset_output_gb/_SUCCESS
-rw-r--r--  1 ubuntu supergroup 99858400 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00000
-rw-r--r--  1 ubuntu supergroup 100079300 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00001
-rw-r--r--  1 ubuntu supergroup 100053400 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00002
-rw-r--r--  1 ubuntu supergroup 100014000 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00003
-rw-r--r--  1 ubuntu supergroup 100040300 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00004
-rw-r--r--  1 ubuntu supergroup 100133300 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00005
-rw-r--r--  1 ubuntu supergroup 100011200 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00006
-rw-r--r--  1 ubuntu supergroup 99986000 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00007
-rw-r--r--  1 ubuntu supergroup 99979700 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00008
-rw-r--r--  1 ubuntu supergroup 99844400 2016-03-19 01:42 hdfs://dataset_output_gb/part-r-00009
ubuntu@ip-172-31-60-26:~/gensort-linux-1.5/64$
```

```

ubuntu@ip-172-31-6-62:~/gensort-linux-1.5/64
total 575140
drwxrwxr-x 2 ubuntu ubuntu 4096 Mar 17 02:53 dataset_output1
drwxrwxr-x 2 ubuntu ubuntu 4096 Mar 19 01:52 gb_data_outut
drwxrwxr-x 4 ubuntu ubuntu 4096 Mar 16 23:49 gensort-linux-1.5
drwxr-xr-x 10 ubuntu ubuntu 4096 Mar 7 16:04 hadoop
drwxr-xr-x 15 ubuntu ubuntu 4096 Jan 26 00:07 hadoop-2.7.2-src
-rw-rw-r-- 1 ubuntu ubuntu 18290860 Mar 7 05:39 hadoop-2.7.2-src.tar.gz
-rw-rw-r-- 1 ubuntu ubuntu 212046774 Mar 7 06:09 hadoop-2.7.2.tar.gz
-rw----- 1 ubuntu ubuntu 1696 Mar 7 05:21 Hadoop.pem
-rw-rw-r-- 1 ubuntu ubuntu 454 Mar 16 03:44 MergeSortThread.class
-rw-r----- 1 ubuntu ubuntu 224 Mar 16 03:44 MergeSortThread.java
-rw-r----- 1 ubuntu ubuntu 29978150 Mar 20 01:05 part-00000
-rw-r----- 1 ubuntu ubuntu 39383118 Mar 18 22:39 part-00029
-rw-rw-r-- 1 ubuntu ubuntu 4421 Mar 19 05:38 SortingExternal.class
-rw-rw-r-- 1 ubuntu ubuntu 8773 Mar 19 05:38 SortingExternal.java
-rw-rw-r-- 1 ubuntu ubuntu 2712 Mar 17 02:51 sort.jar
drwxr-xr-x 14 ubuntu ubuntu 4096 Mar 19 06:10 spark-1.6.0-bin-hadoop2.6
-rw-rw-r-- 1 ubuntu ubuntu 289160984 Mar 7 16:10 spark-1.6.0-bin-hadoop2.6.tgz
-r----- 1 ubuntu ubuntu 1692 Mar 7 16:27 spark.pem
drwxrwxr-x 2 ubuntu ubuntu 4096 Mar 17 01:19 terasort_out
-rw-r----- 1 ubuntu ubuntu 105 Mar 14 16:38 words
ubuntu@ip-172-31-6-62:~$ cd terasort_out
ubuntu@ip-172-31-6-62:~/terasort_out$ ls -l
total 9772
-rw-r----- 1 ubuntu ubuntu 0 Mar 14 19:57 _partition.lst
-rw-r----- 1 ubuntu ubuntu 10000000 Mar 14 19:57 part-r-00000
-rw-r----- 1 ubuntu ubuntu 2691 Mar 17 01:19 sort.jar
-rw-r----- 1 ubuntu ubuntu 0 Mar 14 19:57 _SUCCESS
ubuntu@ip-172-31-6-62:~/terasort_out$ cd ..
ubuntu@ip-172-31-6-62:~$ cd gensort-linux-1.5
ubuntu@ip-172-31-6-62:~/gensort-linux-1.5$ cd 64
Records: 100000
Checksum: c34e19c81885
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-6-62:~/gensort-linux-1.5/64$ ■

```

10 GB:

```

ubuntu@ip-172-31-2-61:~/hadoop/etc/hadoop
16/03/26 19:48:53 INFO mapreduce.Job: map 0% reduce 0%
16/03/26 19:49:22 INFO mapreduce.Job: map 2% reduce 0%
16/03/26 19:49:26 INFO mapreduce.Job: map 3% reduce 0%
16/03/26 19:49:32 INFO mapreduce.Job: map 4% reduce 0%
16/03/26 19:49:46 INFO mapreduce.Job: map 5% reduce 0%
16/03/26 19:49:58 INFO mapreduce.Job: map 6% reduce 0%
16/03/26 19:50:02 INFO mapreduce.Job: map 7% reduce 0%
16/03/26 19:50:10 INFO mapreduce.Job: map 8% reduce 0%
16/03/26 19:50:39 INFO mapreduce.Job: map 9% reduce 0%
16/03/26 19:50:41 INFO mapreduce.Job: map 10% reduce 0%
16/03/26 19:50:45 INFO mapreduce.Job: map 11% reduce 0%
16/03/26 19:50:49 INFO mapreduce.Job: map 12% reduce 0%
16/03/26 19:51:02 INFO mapreduce.Job: map 13% reduce 0%
16/03/26 19:51:13 INFO mapreduce.Job: map 14% reduce 0%
16/03/26 19:51:17 INFO mapreduce.Job: map 15% reduce 0%
16/03/26 19:51:25 INFO mapreduce.Job: map 16% reduce 0%
16/03/26 19:51:53 INFO mapreduce.Job: map 17% reduce 0%
16/03/26 19:51:58 INFO mapreduce.Job: map 18% reduce 0%
16/03/26 19:52:01 INFO mapreduce.Job: map 19% reduce 0%
16/03/26 19:52:07 INFO mapreduce.Job: map 20% reduce 0%
16/03/26 19:52:20 INFO mapreduce.Job: map 21% reduce 0%
16/03/26 19:52:32 INFO mapreduce.Job: map 22% reduce 0%
16/03/26 19:52:36 INFO mapreduce.Job: map 23% reduce 0%
16/03/26 19:52:45 INFO mapreduce.Job: map 24% reduce 0%
16/03/26 19:53:12 INFO mapreduce.Job: map 25% reduce 0%
16/03/26 19:53:16 INFO mapreduce.Job: map 26% reduce 0%
16/03/26 19:53:19 INFO mapreduce.Job: map 27% reduce 0%
16/03/26 19:53:24 INFO mapreduce.Job: map 28% reduce 0%
16/03/26 19:53:37 INFO mapreduce.Job: map 29% reduce 0%
16/03/26 19:53:47 INFO mapreduce.Job: map 30% reduce 0%
16/03/26 19:53:53 INFO mapreduce.Job: map 31% reduce 0%
16/03/26 19:53:59 INFO mapreduce.Job: map 32% reduce 0%
16/03/26 19:54:25 INFO mapreduce.Job: map 32% reduce 1%
16/03/26 19:54:28 INFO mapreduce.Job: map 33% reduce 1%
16/03/26 19:54:32 INFO mapreduce.Job: map 34% reduce 1%
16/03/26 19:54:35 INFO mapreduce.Job: map 35% reduce 2%
16/03/26 19:54:41 INFO mapreduce.Job: map 35% reduce 3%
16/03/26 19:54:48 INFO mapreduce.Job: map 36% reduce 3%
16/03/26 19:54:51 INFO mapreduce.Job: map 36% reduce 4%
16/03/26 19:55:00 INFO mapreduce.Job: map 37% reduce 4% ■

```

```
ubuntu@ip-172-31-2-61: ~/hadoop/sbin
16/03/26 21:06:00 INFO mapreduce.Job: map 65% reduce 21%
16/03/26 21:06:06 INFO mapreduce.Job: map 66% reduce 21%
16/03/26 21:06:19 INFO mapreduce.Job: map 67% reduce 21%
16/03/26 21:06:22 INFO mapreduce.Job: map 68% reduce 21%
16/03/26 21:06:31 INFO mapreduce.Job: map 69% reduce 21%
16/03/26 21:06:36 INFO mapreduce.Job: map 69% reduce 22%
16/03/26 21:06:39 INFO mapreduce.Job: map 69% reduce 23%
16/03/26 21:06:59 INFO mapreduce.Job: map 70% reduce 23%
16/03/26 21:07:00 INFO mapreduce.Job: map 71% reduce 23%
16/03/26 21:07:06 INFO mapreduce.Job: map 72% reduce 23%
16/03/26 21:07:15 INFO mapreduce.Job: map 73% reduce 23%
16/03/26 21:07:24 INFO mapreduce.Job: map 74% reduce 23%
16/03/26 21:07:27 INFO mapreduce.Job: map 75% reduce 23%
16/03/26 21:07:30 INFO mapreduce.Job: map 75% reduce 24%
16/03/26 21:07:34 INFO mapreduce.Job: map 75% reduce 25%
16/03/26 21:08:10 INFO mapreduce.Job: map 76% reduce 25%
16/03/26 21:08:13 INFO mapreduce.Job: map 77% reduce 25%
16/03/26 21:08:22 INFO mapreduce.Job: map 78% reduce 25%
16/03/26 21:08:32 INFO mapreduce.Job: map 79% reduce 25%
16/03/26 21:08:35 INFO mapreduce.Job: map 80% reduce 25%
16/03/26 21:08:41 INFO mapreduce.Job: map 80% reduce 26%
16/03/26 21:08:44 INFO mapreduce.Job: map 80% reduce 27%
16/03/26 21:09:03 INFO mapreduce.Job: map 81% reduce 27%
16/03/26 21:09:06 INFO mapreduce.Job: map 82% reduce 27%
16/03/26 21:09:15 INFO mapreduce.Job: map 83% reduce 27%
16/03/26 21:09:18 INFO mapreduce.Job: map 84% reduce 27%
16/03/26 21:09:28 INFO mapreduce.Job: map 85% reduce 27%
16/03/26 21:09:35 INFO mapreduce.Job: map 85% reduce 28%
16/03/26 21:10:07 INFO mapreduce.Job: map 86% reduce 28%
16/03/26 21:10:12 INFO mapreduce.Job: map 87% reduce 28%
16/03/26 21:10:17 INFO mapreduce.Job: map 88% reduce 28%
16/03/26 21:10:27 INFO mapreduce.Job: map 89% reduce 28%
16/03/26 21:10:35 INFO mapreduce.Job: map 90% reduce 28%
16/03/26 21:10:39 INFO mapreduce.Job: map 91% reduce 28%
16/03/26 21:10:41 INFO mapreduce.Job: map 91% reduce 29%
16/03/26 21:10:44 INFO mapreduce.Job: map 91% reduce 30%
16/03/26 21:11:05 INFO mapreduce.Job: map 92% reduce 30%
16/03/26 21:11:08 INFO mapreduce.Job: map 93% reduce 30%
16/03/26 21:11:20 INFO mapreduce.Job: map 94% reduce 30%
16/03/26 21:11:27 INFO mapreduce.Job: map 95% reduce 30%
```

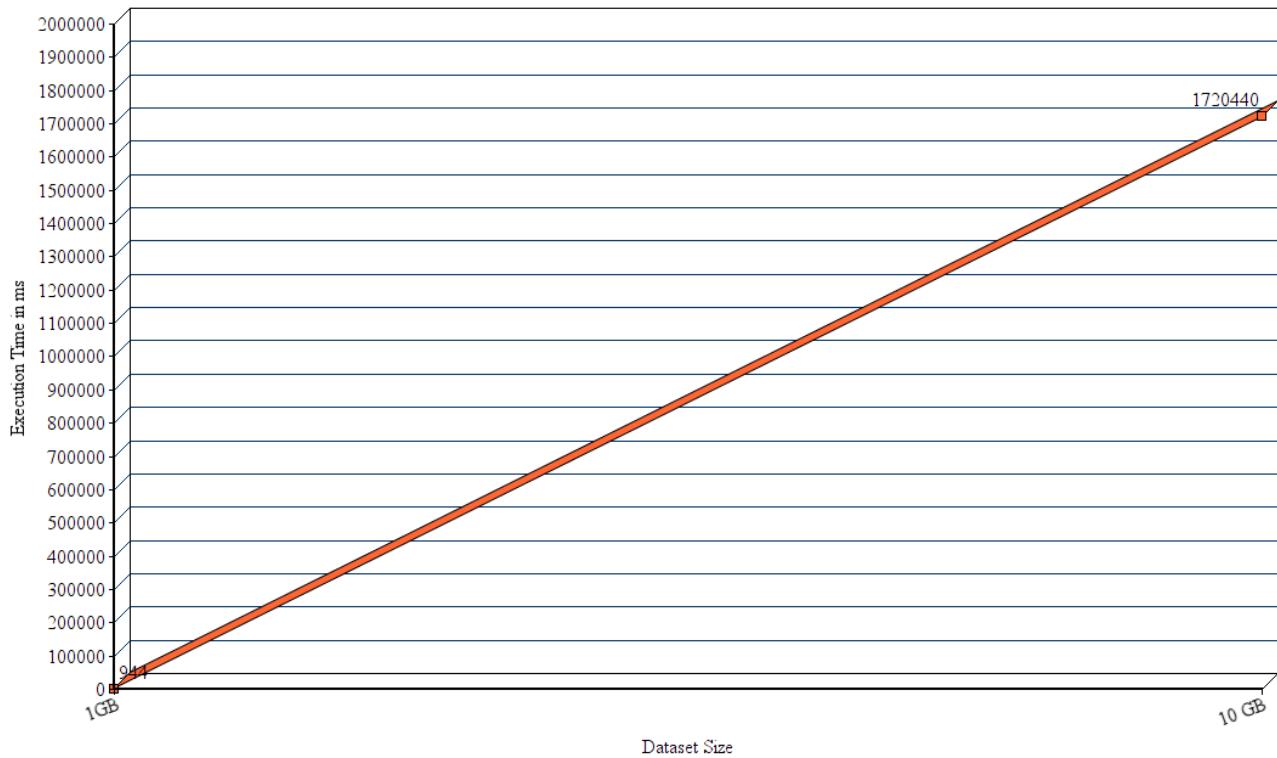
```
ubuntu@ip-172-31-2-61: ~/hadoop/sbin
16/03/26 21:13:43 INFO mapreduce.Job: map 100% reduce 78%
16/03/26 21:13:49 INFO mapreduce.Job: map 100% reduce 79%
16/03/26 21:13:53 INFO mapreduce.Job: map 100% reduce 80%
16/03/26 21:13:58 INFO mapreduce.Job: map 100% reduce 81%
16/03/26 21:14:02 INFO mapreduce.Job: map 100% reduce 82%
16/03/26 21:14:08 INFO mapreduce.Job: map 100% reduce 83%
16/03/26 21:14:13 INFO mapreduce.Job: map 100% reduce 84%
16/03/26 21:14:17 INFO mapreduce.Job: map 100% reduce 85%
16/03/26 21:14:24 INFO mapreduce.Job: map 100% reduce 86%
16/03/26 21:14:28 INFO mapreduce.Job: map 100% reduce 87%
16/03/26 21:14:33 INFO mapreduce.Job: map 100% reduce 88%
16/03/26 21:14:39 INFO mapreduce.Job: map 100% reduce 89%
16/03/26 21:14:44 INFO mapreduce.Job: map 100% reduce 90%
16/03/26 21:14:48 INFO mapreduce.Job: map 100% reduce 91%
16/03/26 21:14:54 INFO mapreduce.Job: map 100% reduce 92%
16/03/26 21:14:59 INFO mapreduce.Job: map 100% reduce 93%
16/03/26 21:15:03 INFO mapreduce.Job: map 100% reduce 94%
16/03/26 21:15:09 INFO mapreduce.Job: map 100% reduce 95%
16/03/26 21:15:14 INFO mapreduce.Job: map 100% reduce 96%
16/03/26 21:15:19 INFO mapreduce.Job: map 100% reduce 97%
16/03/26 21:15:25 INFO mapreduce.Job: map 100% reduce 98%
16/03/26 21:15:30 INFO mapreduce.Job: map 100% reduce 99%
16/03/26 21:15:34 INFO mapreduce.Job: map 100% reduce 100%
16/03/26 21:15:36 INFO mapreduce.Job: Job job_1459025643951_0001 completed successfully
16/03/26 21:15:36 INFO mapreduce.Job: Counters: 50
    File System Counters
        FILE: Number of bytes read=30256623768
        FILE: Number of bytes written=40465468889
        FILE: Number of read operations=0
        FILE: Number of large read operations=0
        FILE: Number of write operations=0
        HDFS: Number of bytes read=10000313004
        HDFS: Number of bytes written=100000000000
        HDFS: Number of read operations=231
        HDFS: Number of large read operations=0
        HDFS: Number of write operations=4
    Job Counters
        Killed map tasks=1
        Launched map tasks=76
        Launched reduce tasks=2
        Data-local map tasks=76
```

```
ubuntu@ip-172-31-2-61: ~/hadoop/sbin
Total time spent by all maps in occupied slots (ms)=4014662
Total time spent by all reduces in occupied slots (ms)=2021556
Total time spent by all map tasks (ms)=4014662
Total time spent by all reduce tasks (ms)=2021556
Total vcore-milliseconds taken by all map tasks=4014662
Total vcore-milliseconds taken by all reduce tasks=2021556
Total megabyte-milliseconds taken by all map tasks=411013888
Total megabyte-milliseconds taken by all reduce tasks=2070073344
Map-Reduce Framework
  Map input records=100000000
  Map output records=100000000
  Map output bytes=10000000000
  Map output materialized bytes=10200000900
  Input split bytes=9900
  Combine input records=100000000
  Combine output records=100000000
  Reduce input groups=100000000
  Reduce shuffle bytes=10200000900
  Reduce input records=100000000
  Reduce output records=100000000
  Spilled Records=396630522
  Shuffled Maps =150
  Failed Shuffles=0
  Merged Map outputs=150
  GC time elapsed (ms)=68470
  CPU time spent (ms)=1720440
  Physical memory (bytes) snapshot=20323581952
  Virtual memory (bytes) snapshot=63765053440
  Total committed heap usage (bytes)=15821963264
  Shuffle Errors
    BAD_ID=0
    CONNECTION=0
    IO_ERROR=0
    WRONG_LENGTH=0
    WRONG_MAP=0
    WRONG_REDUCE=0
  File Input Format Counters
    Bytes Read=10000303104
  File Output Format Counters
    Bytes Written=100000000000
ubuntu@ip-172-31-2-61:~/hadoop/sbin$
```

```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64
-rw-rw-r-- 1 ubuntu ubuntu 4447 Mar 16 03:44 SortingExternal.class
-rw-rw-r-- 1 ubuntu ubuntu 8594 Mar 16 03:44 SortingExternal.java
-rw-rw-r-- 1 ubuntu ubuntu 2710 Mar 20 19:37 sort.jar
drwxr-xr-x 12 ubuntu ubuntu 4096 Mar 16 03:02 spark-1.6.0-bin-hadoop2.6
-r----- 1 ubuntu ubuntu 1692 Mar 7 16:27 spark.pem
ubuntu@ip-172-31-2-61:~$ unix2dos hadoop_tengb_firstellen_output
unix2dos: converting file hadoop_tengb_firstellen_output to DOS format ...
ubuntu@ip-172-31-2-61:~$ unix2dos hadoop_tengb_lastten_output
unix2dos: converting file hadoop_tengb_lastten_output to DOS format ...
ubuntu@ip-172-31-2-61:~$ cd gensort-linux-1.5
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5$ cd 64
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb_firstellen_output
sump pump fatal error: pfunc_get_rec: partial record of 12 bytes found at end of input
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb.lastten_output
sump pump fatal error: pfunc_get_rec: partial record of 10 bytes found at end of input
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ unix2dos /home/ubuntu/hadoop_tengb_firstellen_output
unix2dos: converting file /home/ubuntu/hadoop_tengb_firstellen_output to DOS format ...
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb.lastten_output
sump pump fatal error: pfunc_get_rec: partial record of 10 bytes found at end of input
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ vi /home/ubuntu/hadoop_tengb_firstellen_output
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb.lastten_output
sump pump fatal error: pfunc_get_rec: partial record of 10 bytes found at end of input
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ dos2unix hadoop_tengb_firstellen_output
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ dos2unix hadoop_tengb.lastten_output
dos2unix: hadoop_tengb_firstellen_output: No such file or directory
dos2unix: Skipping hadoop_tengb_firstellen_output, not a regular file.
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ dos2unix /home/ubuntu/hadoop_tengb_firstellen_output
dos2unix: converting file /home/ubuntu/hadoop_tengb_firstellen_output to Unix format ...
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb_firstellen_output
Records: 10
Checksum: 514813dd9
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ dos2unix /home/ubuntu/hadoop_tengb.lastten_output
dos2unix: converting file /home/ubuntu/hadoop_tengb.lastten_output to Unix format ...
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/hadoop_tengb.lastten_output
Records: 10
Checksum: 55f3eae00
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$
```

## Performance: Execution Time (ms)

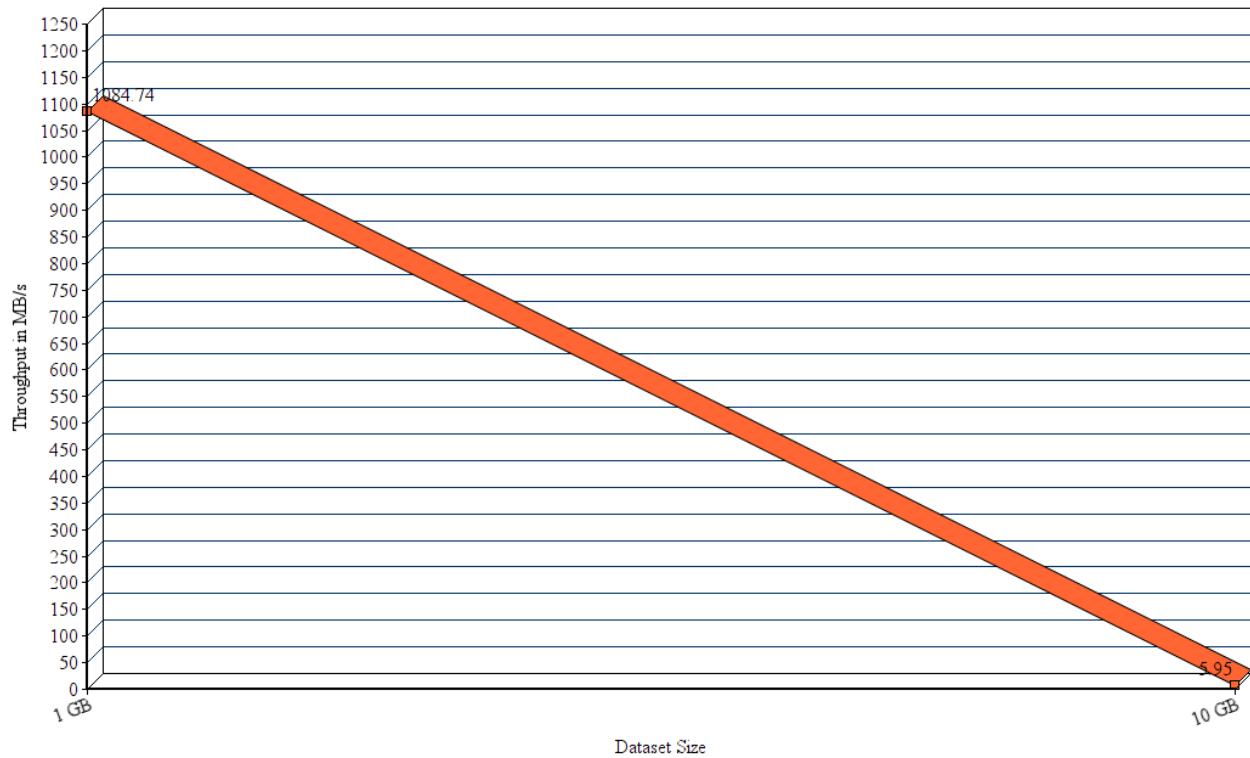
Hadoop Single Node



The graph shows a linear increase in execution time as the dataset size increases.

## Throughput in MB/s:

Hadoop Single Node



The throughput drops for higher dataset size as there is a large increase in the execution time. This is the case for Hadoop running on a single node.

## 16 node Cluster:

1 GB

```
ubuntu@ip-172-31-1-145:~/hadoop/bin
ubuntu@ip-172-31-1-145:~/pssh-2.3.1$ cd ..
ubuntu@ip-172-31-1-145:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/dataset_gb
sp_start failed: /mnt/raid/dataset_gb: Permission denied

ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ chmod gensort
chmod: missing operand after 'gensort'
Try 'chmod --help' for more information.

ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ chmod 777 gensort
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/dataset_gb
sp_start failed: /mnt/raid/dataset_gb: Permission denied

ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ sudo su
root@ip-172-31-1-145:/home/ubuntu/gensort-linux-1.5/64# chmod 777 /mnt/raid
root@ip-172-31-1-145:/home/ubuntu/gensort-linux-1.5/64# exit
exit
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ./gensort -a 10000000 /mnt/raid/dataset_gb
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ cd ..
ubuntu@ip-172-31-1-145:~$ cd hadoop/bin
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop fs -put /mnt/raid/dataset_gb hdfs:/
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop fs -ls hdfs:/
Found 1 items
-rw-r--r-- 1 ubuntu supergroup 1000000000 2016-03-20 05:02 hdfs:///dataset_gb
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop jar /home/ubuntu/sort.jar hdfs:///dataset_gb hdfs:///output_gb
16/03/20 05:03:00 INFO client.RMProxy: Connecting to ResourceManager at ec2-52-90-156-7.compute-1.amazonaws.com/172.31.1.145:8032
16/03/20 05:03:00 INFO input.FileInputFormat: Total input paths to process : 1
16/03/20 05:03:00 INFO mapreduce.JobSubmitter: number of splits:8
16/03/20 05:03:00 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1458449808490_0001
16/03/20 05:03:01 INFO impl.YarnClientImpl: Submitted application application_1458449808490_0001
16/03/20 05:03:01 INFO mapreduce.Job: The url to track the job: http://ec2-52-90-156-7.compute-1.amazonaws.com:8088/proxy/application_1458449808490_0001/
16/03/20 05:03:01 INFO mapreduce.Job: Running job: job_1458449808490_0001
16/03/20 05:03:08 INFO mapreduce.Job: Job job_1458449808490_0001 running in uber mode : false
16/03/20 05:03:08 INFO mapreduce.Job: map 0% reduce 0%
16/03/20 05:03:16 INFO mapreduce.Job: map 13% reduce 0%
16/03/20 05:03:26 INFO mapreduce.Job: map 18% reduce 0%
16/03/20 05:03:27 INFO mapreduce.Job: map 33% reduce 1%
16/03/20 05:03:28 INFO mapreduce.Job: map 33% reduce 4%
16/03/20 05:03:29 INFO mapreduce.Job: map 37% reduce 4%
16/03/20 05:03:30 INFO mapreduce.Job: map 48% reduce 4%
```

```
ubuntu@ip-172-31-1-145:~/hadoop/bin
ubuntu@ip-172-31-1-145:~$ cd hadoop/bin
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop fs -put /mnt/raid/dataset_gb hdfs:/
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop fs -ls hdfs:/
Found 1 items
-rw-r--r-- 1 ubuntu supergroup 1000000000 2016-03-20 05:02 hdfs:///dataset_gb
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop jar /home/ubuntu/sort.jar hdfs:///dataset_gb hdfs:///output_gb
16/03/20 05:03:00 INFO client.RMProxy: Connecting to ResourceManager at ec2-52-90-156-7.compute-1.amazonaws.com/172.31.1.145:8032
16/03/20 05:03:00 INFO input.FileInputFormat: Total input paths to process : 1
16/03/20 05:03:00 INFO mapreduce.JobSubmitter: number of splits:8
16/03/20 05:03:00 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1458449808490_0001
16/03/20 05:03:01 INFO impl.YarnClientImpl: Submitted application application_1458449808490_0001
16/03/20 05:03:01 INFO mapreduce.Job: The url to track the job: http://ec2-52-90-156-7.compute-1.amazonaws.com:8088/proxy/application_1458449808490_0001/
16/03/20 05:03:01 INFO mapreduce.Job: Running job: job_1458449808490_0001
16/03/20 05:03:08 INFO mapreduce.Job: Job job_1458449808490_0001 running in uber mode : false
16/03/20 05:03:08 INFO mapreduce.Job: map 0% reduce 0%
16/03/20 05:03:16 INFO mapreduce.Job: map 13% reduce 0%
16/03/20 05:03:26 INFO mapreduce.Job: map 18% reduce 0%
16/03/20 05:03:27 INFO mapreduce.Job: map 33% reduce 1%
16/03/20 05:03:28 INFO mapreduce.Job: map 33% reduce 4%
16/03/20 05:03:29 INFO mapreduce.Job: map 37% reduce 4%
16/03/20 05:03:30 INFO mapreduce.Job: map 48% reduce 4%
16/03/20 05:03:32 INFO mapreduce.Job: map 49% reduce 4%
16/03/20 05:03:33 INFO mapreduce.Job: map 52% reduce 4%
16/03/20 05:03:36 INFO mapreduce.Job: map 55% reduce 4%
16/03/20 05:03:37 INFO mapreduce.Job: map 59% reduce 4%
16/03/20 05:03:38 INFO mapreduce.Job: map 59% reduce 5%
16/03/20 05:03:39 INFO mapreduce.Job: map 74% reduce 6%
16/03/20 05:03:40 INFO mapreduce.Job: map 74% reduce 8%
16/03/20 05:03:42 INFO mapreduce.Job: map 75% reduce 8%
16/03/20 05:03:45 INFO mapreduce.Job: map 83% reduce 8%
16/03/20 05:03:48 INFO mapreduce.Job: map 98% reduce 8%
16/03/20 05:03:49 INFO mapreduce.Job: map 100% reduce 12%
16/03/20 05:03:50 INFO mapreduce.Job: map 100% reduce 15%
16/03/20 05:03:51 INFO mapreduce.Job: map 100% reduce 19%
16/03/20 05:03:52 INFO mapreduce.Job: map 100% reduce 30%
16/03/20 05:03:53 INFO mapreduce.Job: map 100% reduce 37%
16/03/20 05:03:54 INFO mapreduce.Job: map 100% reduce 55%
16/03/20 05:03:55 INFO mapreduce.Job: map 100% reduce 90%
16/03/20 05:03:56 INFO mapreduce.Job: map 100% reduce 91%
```

```
ubuntu@ip-172-31-1-145: ~/hadoop/bin
      Total time spent by all maps in occupied slots (ms)=284533
      Total time spent by all reduces in occupied slots (ms)=372679
      Total time spent by all map tasks (ms)=284533
      Total time spent by all reduce tasks (ms)=372679
      Total vcore-milliseconds taken by all map tasks=284533
      Total vcore-milliseconds taken by all reduce tasks=372679
      Total megabyte-milliseconds taken by all map tasks=291361792
      Total megabyte-milliseconds taken by all reduce tasks=381623296
Map-Reduce Framework
      Map input records=10000000
      Map output records=10000000
      Map output bytes=1000000000
      Map output materialized bytes=1020000480
      Input split bytes=1016
      Combine input records=10000000
      Combine output records=10000000
      Reduce input groups=10000000
      Reduce shuffle bytes=1020000480
      Reduce input records=10000000
      Reduce output records=10000000
      Spilled Records=29395241
      Shuffled Maps =80
      Failed Shuffles=0
      Merged Map outputs=80
      GC time elapsed (ns)=8924
      CPU time spent (ms)=170410
      Physical memory (bytes) snapshot=5101387776
      Virtual memory (bytes) snapshot=15104196608
      Total committed heap usage (bytes)=3602382848
Shuffle Errors
      BAD_ID=0
      CONNECTION=0
      IO_ERROR=0
      WRONG_LENGTH=0
      WRONG_MAP=0
      WRONG_REDUCE=0
File Input Format Counters
      Bytes Read=1000028672
File Output Format Counters
      Bytes Written=1000000000
ubuntu@ip-172-31-1-145:~/hadoop/bin$
```

```

ubuntu@ip-172-31-1-145: ~/gensort-linux-1.5/64
get: `/home/ubuntu/output_hadoop': File exists
ubuntu@ip-172-31-1-145:~/hadoop/bin$ hadoop fs -get hdfs://output_gb/part-r-00009 /home/ubuntu/output_hadoop
ubuntu@ip-172-31-1-145:~/hadoop/bin$ cd ..
ubuntu@ip-172-31-1-145:~$ ls -l
total 71220
drwxrwxr-x  2 ubuntu ubuntu      4096 Mar 17 02:53 dataset_outputi
drwxrwxr-x  4 ubuntu ubuntu      4096 Mar 16 23:49 gensort-linux-1.5
drwxr-xr-x 10 ubuntu ubuntu     4096 Mar 7 16:04 hadoop
drwxr-xr-x 15 ubuntu ubuntu     4096 Jan 26 00:07 hadoop-2.7.2-src
-rw-rw-r--  1 ubuntu ubuntu 18290860 Mar 7 05:39 hadoop-2.7.2-src.tar.gz
-rw-rw-r--  1 ubuntu ubuntu 212046774 Mar 7 06:09 hadoop-2.7.2.tar.gz
-rw-----  1 ubuntu ubuntu    1696 Mar 7 05:21 Hadoop.pem
-rw-rw-r--  1 ubuntu ubuntu     454 Mar 16 03:44 MergeSortThread.class
-rw-rw-r--  1 ubuntu ubuntu    224 Mar 16 03:44 MergeSortThread.java
-rw-r----- 1 ubuntu ubuntu 99858400 Mar 20 05:06 output_hadoop
-rw-r----- 1 ubuntu ubuntu 99844400 Mar 20 05:06 output_hadoop1
-rw-r----- 1 ubuntu ubuntu 10000000 Mar 17 02:27 part-r-00000
drwxrwxr-x  7 ubuntu ubuntu     4096 Mar 20 04:48 pssh-2.3.1
-rw-rw-r--  1 ubuntu ubuntu 23427 Mar 20 03:32 pssh-2.3.1.tar.gz
-rw-rw-r--  1 ubuntu ubuntu 4447 Mar 16 03:44 SortingExternal.class
-rw-rw-r--  1 ubuntu ubuntu 8594 Mar 16 03:44 SortingExternal.java
-rw-r----- 1 ubuntu ubuntu 2712 Mar 17 02:51 sort.jar
drwxr-xr-x 12 ubuntu ubuntu     4096 Mar 16 03:02 spark-1.6.0-bin-hadoop2.6
-rw-rw-r--  1 ubuntu ubuntu 289160984 Mar 7 16:10 spark-1.6.0-bin-hadoop2.6.tgz
-r-----  1 ubuntu ubuntu    1692 Mar 7 16:27 spark.pem
drwxrwxr-x  2 ubuntu ubuntu     4096 Mar 17 01:19 terasort_out
-rw-r----- 1 ubuntu ubuntu    105 Mar 14 16:38 words
ubuntu@ip-172-31-1-145:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ chmod 777 valsrt
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/output_hadoop
Records: 998584
Checksum: 79e8410f578ba
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ./valsrt /home/ubuntu/output_hadoop1
Records: 998444
Checksum: 79dc0dbfd74d4
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-1-145:~/gensort-linux-1.5/64$ ■

```

100 GB:

```

ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64
-rw----- 1 ubuntu ubuntu 1696 Mar 7 05:21 Hadoop.pem
-rw-rw-r-- 1 ubuntu ubuntu 1000 Mar 26 21:47 hadoop_tengb_firstten_output
-rw-rw-r-- 1 ubuntu ubuntu 1000 Mar 26 21:47 hadoop_tengb_lastten_output
-rw-rw-r-- 1 ubuntu ubuntu 454 Mar 16 03:44 MergeSortThread.class
-rw-rw-r-- 1 ubuntu ubuntu 224 Mar 16 03:44 MergeSortThread.java
drwxrwxr-x 7 ubuntu ubuntu 4096 Mar 27 15:41 pssh-2.3.1
-rw-rw-r-- 1 ubuntu ubuntu 23427 Mar 27 05:13 pssh-2.3.1.tar.gz
-rw-rw-r-- 1 ubuntu ubuntu 4447 Mar 16 03:44 SortingExternal.class
-rw-rw-r-- 1 ubuntu ubuntu 8594 Mar 16 03:44 SortingExternal.java
-rw-r----- 1 ubuntu ubuntu 2710 Mar 27 16:25 sort.jar
drwxr-xr-x 12 ubuntu ubuntu 4096 Mar 16 03:02 spark-1.6.0-bin-hadoop2.6
-r----- 1 ubuntu ubuntu 1692 Mar 7 16:27 spark.pem
ubuntu@ip-172-31-2-61:~$ cd gensort-linux-1.5/64
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./gensort -a 1000000000 /mnt/raid/dataset_hgb
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop fs -put /mnt/raid/dataset_hgb hdfs:/
Found 1 items
-rw-r----- 1 ubuntu supergroup 10000000000 2016-03-27 17:30 hdfs:///dataset_hgb
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ df -h
Filesystem      Size  Used Avail Use% Mounted on
udev            1.9G   12K  1.9G  1% /dev
tmpfs           377M  384K  377M  1% /run
/dev/xvda1       32G   2.6G  28G  9% /
none            4.0K     0  4.0K  0% /sys/fs/cgroup
none            5.0M     0  5.0M  0% /run/lock
none            1.9G     0  1.9G  0% /run/shm
none           100M     0 100M  0% /run/user
afs             8.6G     0  8.6G  0% /afs
/dev/mdd         985G  188G  748G 21% /mnt/raid
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop jar /home/ubuntu/sort.jar hdfs://dataset_hgb hdfs:///dataset_hgb_output
16/03/27 17:35:57 INFO client.RMProxy: Connecting to ResourceManager at ec2-52-90-221-145.compute-1.amazonaws.com:172.31.2.61:8032
16/03/27 17:35:58 INFO mapreduce.JobSubmitter: number of splits:745
16/03/27 17:35:59 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1459095883712_0001
16/03/27 17:35:59 INFO impl.YarnClientImpl: Submitted application application_1459095883712_0001
16/03/27 17:35:59 INFO mapreduce.Job: The url to track the job: http://ec2-52-90-221-145.compute-1.amazonaws.com:8088/proxy/application_1459095883712_0001/
16/03/27 17:35:59 INFO mapreduce.Job: Running job: job_1459095883712_0001
16/03/27 17:36:08 INFO mapreduce.Job: Job job_1459095883712_0001 running in uber mode : false
16/03/27 17:36:08 INFO mapreduce.Job: map 0% reduce 0%
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ■

```

```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64
16/03/27 19:06:39 INFO mapreduce.Job: map 100% reduce 44%
16/03/27 19:06:42 INFO mapreduce.Job: map 100% reduce 45%
16/03/27 19:06:45 INFO mapreduce.Job: map 100% reduce 46%
16/03/27 19:06:48 INFO mapreduce.Job: map 100% reduce 47%
16/03/27 19:06:51 INFO mapreduce.Job: map 100% reduce 48%
16/03/27 19:06:54 INFO mapreduce.Job: map 100% reduce 49%
16/03/27 19:06:57 INFO mapreduce.Job: map 100% reduce 50%
16/03/27 19:07:00 INFO mapreduce.Job: map 100% reduce 51%
16/03/27 19:07:03 INFO mapreduce.Job: map 100% reduce 52%
16/03/27 19:07:06 INFO mapreduce.Job: map 100% reduce 53%
16/03/27 19:07:09 INFO mapreduce.Job: map 100% reduce 54%
16/03/27 19:07:12 INFO mapreduce.Job: map 100% reduce 55%
16/03/27 19:07:15 INFO mapreduce.Job: map 100% reduce 57%
16/03/27 19:07:18 INFO mapreduce.Job: map 100% reduce 58%
16/03/27 19:07:24 INFO mapreduce.Job: map 100% reduce 59%
16/03/27 19:07:27 INFO mapreduce.Job: map 100% reduce 60%
16/03/27 19:07:33 INFO mapreduce.Job: map 100% reduce 61%
16/03/27 19:07:39 INFO mapreduce.Job: map 100% reduce 62%
16/03/27 19:07:45 INFO mapreduce.Job: map 100% reduce 63%
16/03/27 19:07:48 INFO mapreduce.Job: map 100% reduce 64%
16/03/27 19:07:54 INFO mapreduce.Job: map 100% reduce 65%
16/03/27 19:08:00 INFO mapreduce.Job: map 100% reduce 66%
16/03/27 19:08:03 INFO mapreduce.Job: map 100% reduce 67%
16/03/27 19:08:09 INFO mapreduce.Job: map 100% reduce 68%
16/03/27 19:08:55 INFO mapreduce.Job: map 100% reduce 69%
16/03/27 19:09:46 INFO mapreduce.Job: map 100% reduce 70%
16/03/27 19:10:31 INFO mapreduce.Job: map 100% reduce 71%
16/03/27 19:11:22 INFO mapreduce.Job: map 100% reduce 72%
16/03/27 19:12:10 INFO mapreduce.Job: map 100% reduce 73%
16/03/27 19:12:59 INFO mapreduce.Job: map 100% reduce 74%
16/03/27 19:13:47 INFO mapreduce.Job: map 100% reduce 75%
16/03/27 19:14:38 INFO mapreduce.Job: map 100% reduce 76%
16/03/27 19:15:26 INFO mapreduce.Job: map 100% reduce 77%
16/03/27 19:16:14 INFO mapreduce.Job: map 100% reduce 78%
16/03/27 19:17:03 INFO mapreduce.Job: map 100% reduce 79%
16/03/27 19:17:51 INFO mapreduce.Job: map 100% reduce 80%
16/03/27 19:18:39 INFO mapreduce.Job: map 100% reduce 81%
16/03/27 19:19:30 INFO mapreduce.Job: map 100% reduce 82%
16/03/27 19:20:19 INFO mapreduce.Job: map 100% reduce 83%
16/03/27 19:21:07 INFO mapreduce.Job: map 100% reduce 84%
```

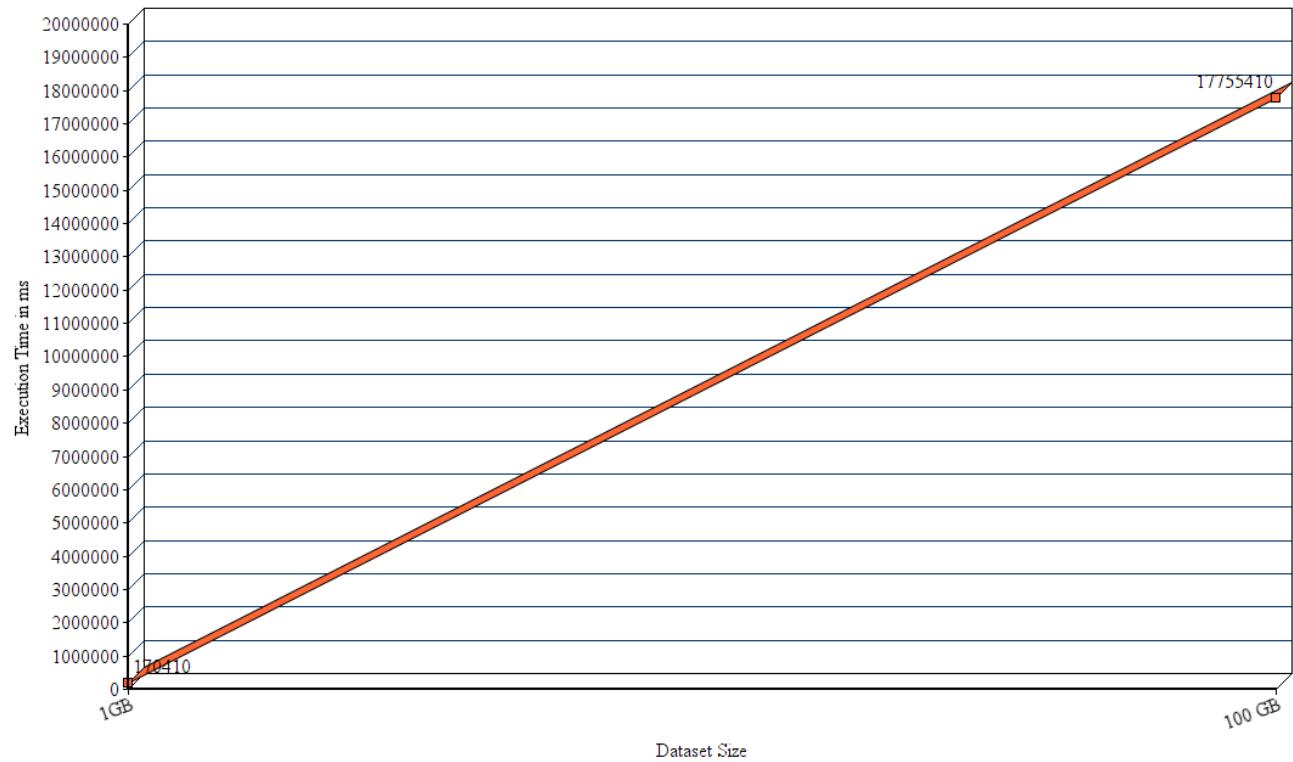
```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64
16/03/27 19:17:03 INFO mapreduce.Job: map 100% reduce 79%
16/03/27 19:17:51 INFO mapreduce.Job: map 100% reduce 80%
16/03/27 19:18:39 INFO mapreduce.Job: map 100% reduce 81%
16/03/27 19:19:30 INFO mapreduce.Job: map 100% reduce 82%
16/03/27 19:20:19 INFO mapreduce.Job: map 100% reduce 83%
16/03/27 19:21:07 INFO mapreduce.Job: map 100% reduce 84%
16/03/27 19:21:55 INFO mapreduce.Job: map 100% reduce 85%
16/03/27 19:22:44 INFO mapreduce.Job: map 100% reduce 86%
16/03/27 19:23:34 INFO mapreduce.Job: map 100% reduce 87%
16/03/27 19:24:22 INFO mapreduce.Job: map 100% reduce 88%
16/03/27 19:25:11 INFO mapreduce.Job: map 100% reduce 89%
16/03/27 19:25:59 INFO mapreduce.Job: map 100% reduce 90%
16/03/27 19:26:58 INFO mapreduce.Job: map 100% reduce 91%
16/03/27 19:27:38 INFO mapreduce.Job: map 100% reduce 92%
16/03/27 19:28:27 INFO mapreduce.Job: map 100% reduce 93%
16/03/27 19:29:15 INFO mapreduce.Job: map 100% reduce 94%
16/03/27 19:30:03 INFO mapreduce.Job: map 100% reduce 95%
16/03/27 19:30:54 INFO mapreduce.Job: map 100% reduce 96%
16/03/27 19:31:40 INFO mapreduce.Job: map 100% reduce 97%
16/03/27 19:32:30 INFO mapreduce.Job: map 100% reduce 98%
16/03/27 19:33:18 INFO mapreduce.Job: map 100% reduce 99%
16/03/27 19:34:07 INFO mapreduce.Job: map 100% reduce 100%
16/03/27 19:34:35 INFO mapreduce.Job: Job job_1459095883712_0001 completed successfully
16/03/27 19:34:36 INFO mapreduce.Job: Counters: 51
      File System Counters
          FILE: Number of bytes read=559235439972
          FILE: Number of bytes written=661321158493
          FILE: Number of read operations=0
          FILE: Number of large read operations=0
          FILE: Number of write operations=0
          HDFS: Number of bytes read=100003144274
          HDFS: Number of bytes written=1000000000000
          HDFS: Number of read operations=2241
          HDFS: Number of large read operations=0
          HDFS: Number of write operations=4
      Job Counters
          Killed map tasks=1
          Launched map tasks=746
          Launched reduce tasks=2
          Data-local map tasks=62
          Rack-local map tasks=684
```

```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64$ Total time spent by all maps in occupied slots (ms)=18822993
Total time spent by all reduces in occupied slots (ms)=13703527
Total time spent by all map tasks (ms)=18822993
Total time spent by all reduce tasks (ms)=13703527
Total vcore-milliseconds taken by all map tasks=18822993
Total vcore-milliseconds taken by all reduce tasks=13703527
Total megabyte-milliseconds taken by all map tasks=19274744832
Total megabyte-milliseconds taken by all reduce tasks=14032411648
Map-Reduce Framework
  Map input records=1000000000
  Map output records=1000000000
  Map output bytes=100000000000
  Map output materialized bytes=102000008940
  Input split bytes=96850
  Combine input records=1000000000
  Combine output records=1000000000
  Reduce input groups=1000000000
  Reduce shuffle bytes=102000008940
  Reduce input records=1000000000
  Reduce output records=1000000000
  Spilled Records=6482669886
  Shuffled Maps =1490
  Failed Shuffles=0
  Merged Map outputs=1490
  GC time elapsed (ms)=413236
  CPU time spent (ms)=17755410
  Physical memory (bytes) snapshot=209058295808
  Virtual memory (bytes) snapshot=618193387520
  Total committed heap usage (bytes)=156023390208
Shuffle Errors
  BAD_ID=0
  CONNECTION=0
  IO_ERROR=0
  WRONG_LENGTH=0
  WRONG_MAP=0
  WRONG_REDUCE=0
File Input Format Counters
  Bytes Read=100003047424
File Output Format Counters
  Bytes Written=100000000000
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$
```

```
ubuntu@ip-172-31-2-61: ~/gensort-linux-1.5/64$ File Output Format Counters
  Bytes Written=100000000000
Filesystem      Size  Used Avail Use% Mounted on
udev            1.9G   12K  1.9G  1% /dev
tmpfs           377M  388K  377M  1% /run
/dev/xvda1       32G   2.6G   28G  9% /
none            4.0K     0  4.0K  0% /sys/fs/cgroup
none            5.0M     0  5.0M  0% /run/lock
none            1.9G     0  1.9G  0% /run/shm
none            100M    0  100M  0% /run/user
AFS              8.6G    0  8.6G  0% /afs
/dev/md0          985G  281G  654G  31% /mnt/raid
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop fs -ls hdfs:/
Found 3 items
-rw-r--r--  1 ubuntu supergroup 100000000000 2016-03-27 17:30 hdfs:///dataset_hgb
drwxr-xr-x  - ubuntu supergroup          0 2016-03-27 19:34 hdfs:///dataset_hgb_output
drwx-----  - ubuntu supergroup          0 2016-03-27 17:35 hdfs:///tmp
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop fs -ls hdfs:///dataset_hgb_output
Found 3 items
-rw-r--r--  1 ubuntu supergroup          0 2016-03-27 19:34 hdfs:///dataset_hgb_output/_SUCCESS
-rw-r--r--  1 ubuntu supergroup 49999526400 2016-03-27 19:34 hdfs:///dataset_hgb_output/part-r-00000
-rw-r--r--  1 ubuntu supergroup 50000473600 2016-03-27 19:34 hdfs:///dataset_hgb_output/part-r-00001
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop fs -get hdfs:///dataset_hgb_output/part-r-00000 /mnt/raid
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ hadoop fs -get hdfs:///dataset_hgb_output/part-r-00001 /mnt/raid
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ head /mnt/raid/part-r-00000 > hadoop_16_node_output
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ tail /mnt/raid/part-r-00001 > hadoop_16_node_output
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ls -l
total 117480
-rwxrwxr-x 1 ubuntu ubuntu 10000000 Mar 17 01:27 dataset_new
-rwxrwxr-x 1 ubuntu ubuntu 10000000 Mar 17 01:28 dataset_new1
-rwxrwxrwx 1 ubuntu ubuntu 141045 Mar 14 19:50 gensort
-rw-rw-r-- 1 ubuntu ubuntu 1000 Mar 27 20:09 hadoop_16_node_output
-rw-rw-r-- 1 ubuntu ubuntu 10000000 Mar 14 20:03 part-r-00000
-rwxrwxrwx 1 ubuntu ubuntu 134558 Mar 14 19:50 valsort
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$ ./valsrt hadoop_16_node_output
Records: 10
Checksum: 37db56e9f
Duplicate keys: 0
SUCCESS - all records are in order
ubuntu@ip-172-31-2-61:~/gensort-linux-1.5/64$
```

## Performance: Execution Time in ms

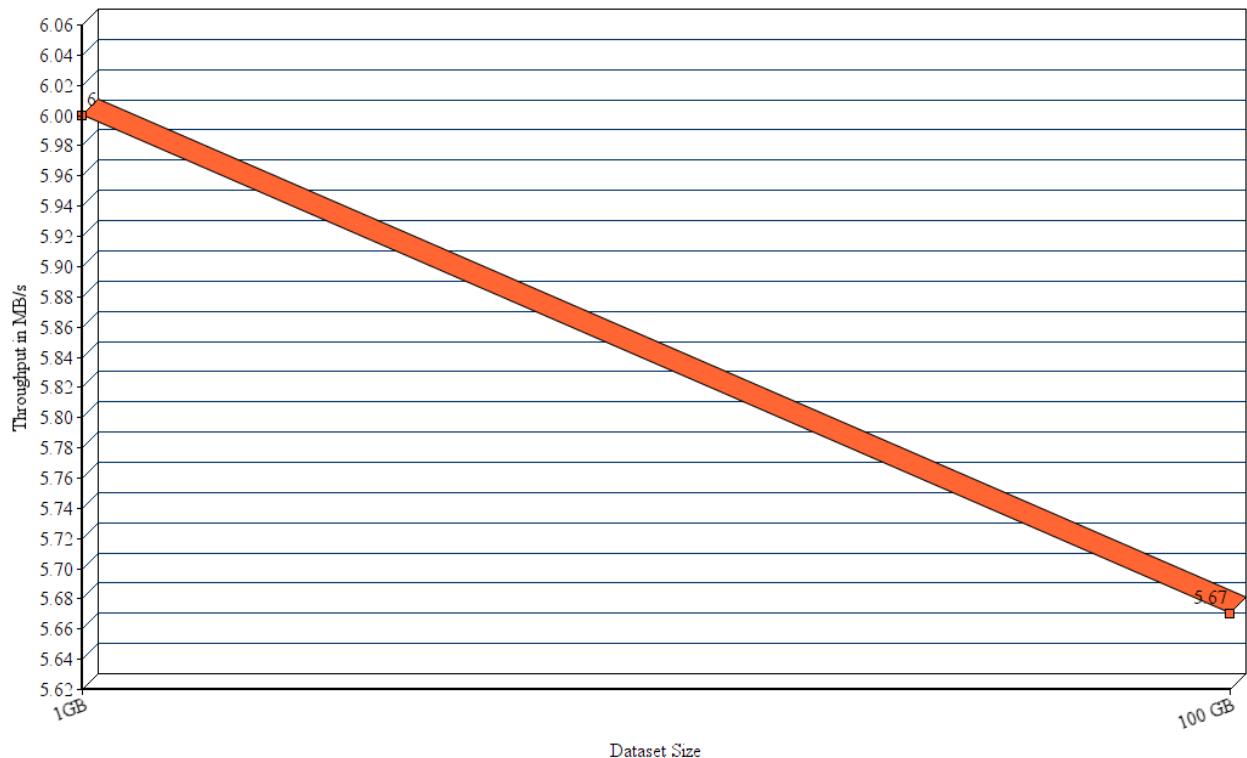
Hadoop 16 Node Cluster



There is a linear increase in execution time as the dataset size increases from 1 GB to 100 GB for a 16 node cluster. The time taken for executing on a 16 node cluster is higher than the one for single node.

## Throughput in MB/s:

Hadoop 16 Node Cluster

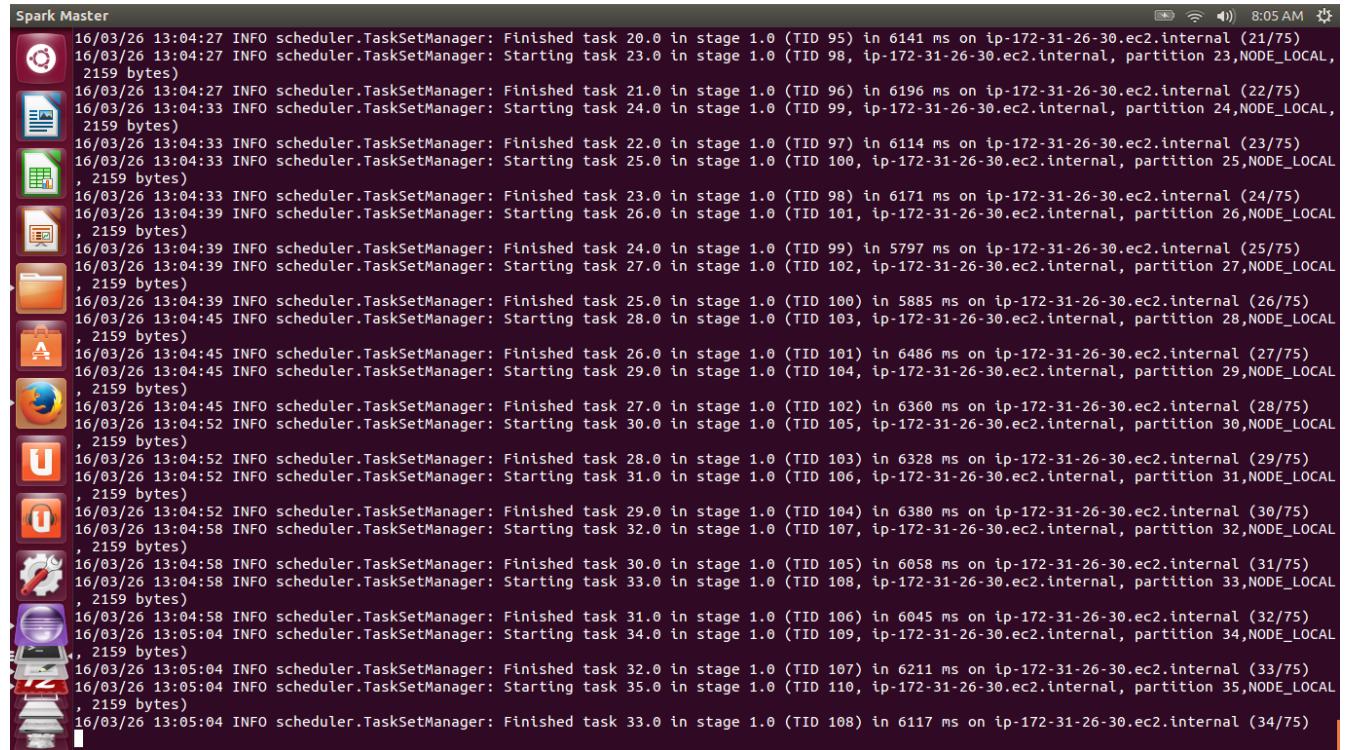


The throughput is nearly same for 1 GB and 100 GB with a slight reduction for higher dataset size due to time taken for the run.

## Spark:

### Single Node:

10 GB



```
Spark Master
16/03/26 13:04:27 INFO scheduler.TaskSetManager: Finished task 20.0 in stage 1.0 (TID 95) in 6141 ms on ip-172-31-26-30.ec2.internal (21/75)
16/03/26 13:04:27 INFO scheduler.TaskSetManager: Starting task 23.0 in stage 1.0 (TID 98, ip-172-31-26-30.ec2.internal, partition 23,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:27 INFO scheduler.TaskSetManager: Finished task 21.0 in stage 1.0 (TID 96) in 6196 ms on ip-172-31-26-30.ec2.internal (22/75)
16/03/26 13:04:33 INFO scheduler.TaskSetManager: Starting task 24.0 in stage 1.0 (TID 99, ip-172-31-26-30.ec2.internal, partition 24,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:33 INFO scheduler.TaskSetManager: Finished task 22.0 in stage 1.0 (TID 97) in 6114 ms on ip-172-31-26-30.ec2.internal (23/75)
16/03/26 13:04:33 INFO scheduler.TaskSetManager: Starting task 25.0 in stage 1.0 (TID 100, ip-172-31-26-30.ec2.internal, partition 25,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:33 INFO scheduler.TaskSetManager: Finished task 23.0 in stage 1.0 (TID 98) in 6171 ms on ip-172-31-26-30.ec2.internal (24/75)
16/03/26 13:04:39 INFO scheduler.TaskSetManager: Starting task 26.0 in stage 1.0 (TID 101, ip-172-31-26-30.ec2.internal, partition 26,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:39 INFO scheduler.TaskSetManager: Finished task 24.0 in stage 1.0 (TID 99) in 5797 ms on ip-172-31-26-30.ec2.internal (25/75)
16/03/26 13:04:39 INFO scheduler.TaskSetManager: Starting task 27.0 in stage 1.0 (TID 102, ip-172-31-26-30.ec2.internal, partition 27,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:39 INFO scheduler.TaskSetManager: Finished task 25.0 in stage 1.0 (TID 100) in 5885 ms on ip-172-31-26-30.ec2.internal (26/75)
16/03/26 13:04:45 INFO scheduler.TaskSetManager: Starting task 28.0 in stage 1.0 (TID 103, ip-172-31-26-30.ec2.internal, partition 28,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:45 INFO scheduler.TaskSetManager: Finished task 26.0 in stage 1.0 (TID 101) in 6486 ms on ip-172-31-26-30.ec2.internal (27/75)
16/03/26 13:04:45 INFO scheduler.TaskSetManager: Starting task 29.0 in stage 1.0 (TID 104, ip-172-31-26-30.ec2.internal, partition 29,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:45 INFO scheduler.TaskSetManager: Finished task 27.0 in stage 1.0 (TID 102) in 6360 ms on ip-172-31-26-30.ec2.internal (28/75)
16/03/26 13:04:52 INFO scheduler.TaskSetManager: Starting task 30.0 in stage 1.0 (TID 105, ip-172-31-26-30.ec2.internal, partition 30,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:52 INFO scheduler.TaskSetManager: Finished task 28.0 in stage 1.0 (TID 103) in 6328 ms on ip-172-31-26-30.ec2.internal (29/75)
16/03/26 13:04:52 INFO scheduler.TaskSetManager: Starting task 31.0 in stage 1.0 (TID 106, ip-172-31-26-30.ec2.internal, partition 31,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:52 INFO scheduler.TaskSetManager: Finished task 29.0 in stage 1.0 (TID 104) in 6380 ms on ip-172-31-26-30.ec2.internal (30/75)
16/03/26 13:04:58 INFO scheduler.TaskSetManager: Starting task 32.0 in stage 1.0 (TID 107, ip-172-31-26-30.ec2.internal, partition 32,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:58 INFO scheduler.TaskSetManager: Finished task 30.0 in stage 1.0 (TID 105) in 6058 ms on ip-172-31-26-30.ec2.internal (31/75)
16/03/26 13:04:58 INFO scheduler.TaskSetManager: Starting task 33.0 in stage 1.0 (TID 108, ip-172-31-26-30.ec2.internal, partition 33,NODE_LOCAL, 2159 bytes)
16/03/26 13:04:58 INFO scheduler.TaskSetManager: Finished task 31.0 in stage 1.0 (TID 106) in 6045 ms on ip-172-31-26-30.ec2.internal (32/75)
16/03/26 13:05:04 INFO scheduler.TaskSetManager: Starting task 34.0 in stage 1.0 (TID 109, ip-172-31-26-30.ec2.internal, partition 34,NODE_LOCAL, 2159 bytes)
16/03/26 13:05:04 INFO scheduler.TaskSetManager: Finished task 32.0 in stage 1.0 (TID 107) in 6211 ms on ip-172-31-26-30.ec2.internal (33/75)
16/03/26 13:05:04 INFO scheduler.TaskSetManager: Starting task 35.0 in stage 1.0 (TID 110, ip-172-31-26-30.ec2.internal, partition 35,NODE_LOCAL, 2159 bytes)
16/03/26 13:05:04 INFO scheduler.TaskSetManager: Finished task 33.0 in stage 1.0 (TID 108) in 6117 ms on ip-172-31-26-30.ec2.internal (34/75)
```

Spark Master

```
scala> :paste
// Entering paste mode (ctrl-D to finish)

val startTime = System.nanoTime
val file = sc.textFile("hdfs:///dataset_tengb")
val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey(true,40).saveAsTextFile("/mnt/raid/output_tgb")

val duration_taken = System.nanoTime - startTime
// Exiting paste mode, now interpreting.

16/03/26 13:02:22 INFO storage.MemoryStore: Block broadcast_0 stored as values in memory (estimated size 26.5 KB, free 26.5 KB)
16/03/26 13:02:22 INFO storage.MemoryStore: Block broadcast_0_piece0 stored as bytes in memory (estimated size 5.6 KB, free 32.1 KB)
16/03/26 13:02:22 INFO storage.BlockManagerInfo: Added broadcast_0_piece0 in memory on 172.31.18.13:40142 (size: 5.6 KB, free: 511.5 MB)
16/03/26 13:02:22 INFO spark.SparkContext: Created broadcast 0 from textFile at <console>:22
16/03/26 13:02:22 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Ubuntu Software Center N snappy.Loadsnappy: Snappy native library not loaded
mapred.FileInputFormat: Total input paths to process : 1
16/03/26 13:02:23 INFO spark.SparkContext: Starting job: sortByKey at <console>:23
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Got job 0 (sortByKey at <console>:23) with 75 output partitions
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Final stage: ResultStage 0 (sortByKey at <console>:23)
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Parents of final stage: List()
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Missing parents: List()
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Submitting ResultStage 0 (MapPartitionsRDD[4] at sortByKey at <console>:23), which has no missing parents
16/03/26 13:02:23 INFO storage.MemoryStore: Block broadcast_1 stored as values in memory (estimated size 3.7 KB, free 35.8 KB)
16/03/26 13:02:23 INFO storage.MemoryStore: Block broadcast_1_piece0 stored as bytes in memory (estimated size 2.0 KB, free 37.8 KB)
16/03/26 13:02:23 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on 172.31.18.13:40142 (size: 2.0 KB, free: 511.5 MB)
16/03/26 13:02:23 INFO spark.SparkContext: Created broadcast 1 from broadcast at DAGScheduler.scala:1006
16/03/26 13:02:23 INFO scheduler.DAGScheduler: Submitting 75 missing tasks from ResultStage 0 (MapPartitionsRDD[4] at sortByKey at <console>:23)
16/03/26 13:02:23 INFO scheduler.TaskSchedulerImpl: Adding task set 0.0 with 75 tasks
16/03/26 13:02:23 INFO scheduler.TaskSetManager: Starting task 0.0 in stage 0.0 (TID 0, ip-172-31-26-30.ec2.internal, partition 0, NODE_LOCAL, 21 70 bytes)
16/03/26 13:02:23 INFO scheduler.TaskSetManager: Starting task 1.0 in stage 0.0 (TID 1, ip-172-31-26-30.ec2.internal, partition 1, NODE_LOCAL, 21 70 bytes)
16/03/26 13:02:23 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on ip-172-31-26-30.ec2.internal:60756 (size: 2.0 KB, free: 1 539.0 MB)
16/03/26 13:02:24 INFO storage.BlockManagerInfo: Added broadcast_0_piece0 in memory on ip-172-31-26-30.ec2.internal:60756 (size: 5.6 KB, free: 1 539.0 MB)
16/03/26 13:02:27 INFO scheduler.TaskSetManager: Starting task 2.0 in stage 0.0 (TID 2, ip-172-31-26-30.ec2.internal, partition 2, NODE_LOCAL, 21 70 bytes)
```

Spark Master

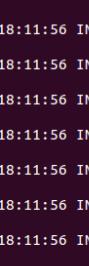
```
16/03/26 13:23:03 INFO scheduler.TaskSetManager: Starting task 30.0 in stage 2.0 (TID 180, ip-172-31-26-30.ec2.internal, partition 30,NODE_LOCAL , 1894 bytes)
16/03/26 13:23:03 INFO scheduler.TaskSetManager: Finished task 28.0 in stage 2.0 (TID 178) in 93785 ms on ip-172-31-26-30.ec2.internal (29/40)
16/03/26 13:24:15 INFO scheduler.TaskSetManager: Starting task 31.0 in stage 2.0 (TID 181, ip-172-31-26-30.ec2.internal, partition 31,NODE_LOCAL , 1894 bytes)
16/03/26 13:24:15 INFO scheduler.TaskSetManager: Finished task 29.0 in stage 2.0 (TID 179) in 76682 ms on ip-172-31-26-30.ec2.internal (30/40)
16/03/26 13:24:19 INFO scheduler.TaskSetManager: Starting task 32.0 in stage 2.0 (TID 182, ip-172-31-26-30.ec2.internal, partition 32,NODE_LOCAL , 1894 bytes)
16/03/26 13:25:19 INFO scheduler.TaskSetManager: Finished task 30.0 in stage 2.0 (TID 180) in 75566 ms on ip-172-31-26-30.ec2.internal (31/40)
16/03/26 13:25:18 INFO scheduler.TaskSetManager: Starting task 33.0 in stage 2.0 (TID 183, ip-172-31-26-30.ec2.internal, partition 33,NODE_LOCAL , 1894 bytes)
16/03/26 13:25:18 INFO scheduler.TaskSetManager: Finished task 31.0 in stage 2.0 (TID 181) in 63384 ms on ip-172-31-26-30.ec2.internal (32/40)
16/03/26 13:25:20 INFO scheduler.TaskSetManager: Starting task 34.0 in stage 2.0 (TID 184, ip-172-31-26-30.ec2.internal, partition 34,NODE_LOCAL , 1894 bytes)
16/03/26 13:25:20 INFO scheduler.TaskSetManager: Finished task 32.0 in stage 2.0 (TID 182) in 61847 ms on ip-172-31-26-30.ec2.internal (33/40)
16/03/26 13:26:41 INFO scheduler.TaskSetManager: Starting task 35.0 in stage 2.0 (TID 185, ip-172-31-26-30.ec2.internal, partition 35,NODE_LOCAL , 1894 bytes)
16/03/26 13:26:41 INFO scheduler.TaskSetManager: Finished task 33.0 in stage 2.0 (TID 183) in 83234 ms on ip-172-31-26-30.ec2.internal (34/40)
16/03/26 13:26:45 INFO scheduler.TaskSetManager: Starting task 36.0 in stage 2.0 (TID 186, ip-172-31-26-30.ec2.internal, partition 36,NODE_LOCAL , 1894 bytes)
16/03/26 13:26:45 INFO scheduler.TaskSetManager: Finished task 34.0 in stage 2.0 (TID 184) in 85040 ms on ip-172-31-26-30.ec2.internal (35/40)
16/03/26 13:28:06 INFO scheduler.TaskSetManager: Starting task 37.0 in stage 2.0 (TID 187, ip-172-31-26-30.ec2.internal, partition 37,NODE_LOCAL , 1894 bytes)
16/03/26 13:28:06 INFO scheduler.TaskSetManager: Finished task 35.0 in stage 2.0 (TID 185) in 85256 ms on ip-172-31-26-30.ec2.internal (36/40)
16/03/26 13:28:10 INFO scheduler.TaskSetManager: Starting task 38.0 in stage 2.0 (TID 188, ip-172-31-26-30.ec2.internal, partition 38,NODE_LOCAL , 1894 bytes)
16/03/26 13:28:10 INFO scheduler.TaskSetManager: Finished task 36.0 in stage 2.0 (TID 186) in 84904 ms on ip-172-31-26-30.ec2.internal (37/40)
16/03/26 13:29:09 INFO scheduler.TaskSetManager: Starting task 39.0 in stage 2.0 (TID 189, ip-172-31-26-30.ec2.internal, partition 39,NODE_LOCAL , 1894 bytes)
16/03/26 13:29:09 INFO scheduler.TaskSetManager: Finished task 37.0 in stage 2.0 (TID 187) in 62580 ms on ip-172-31-26-30.ec2.internal (38/40)
16/03/26 13:29:43 INFO scheduler.TaskSetManager: Finished task 38.0 in stage 2.0 (TID 188) in 93283 ms on ip-172-31-26-30.ec2.internal (39/40)
16/03/26 13:29:59 INFO scheduler.TaskSetManager: Finished task 39.0 in stage 2.0 (TID 189) in 50316 ms on ip-172-31-26-30.ec2.internal (40/40)
16/03/26 13:29:59 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:23) finished in 1364.965 s
16/03/26 13:29:59 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
16/03/26 13:29:59 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextFile at <console>:23, took 1600.071852 s
startTime: Long = 3171839418627
file: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[1] at textFile at <console>:22
<-- Terminal = ()
duration_taken: Long = 1657808615766
scala>
```

```
swathi@swathi-HP-EliteBook-8470p:~/Downloads/gensort-linux-1.5/32$ ./valsrt /home/swathi/Desktop/spark_output_torun_valsrt
Records: 10
Checksum: 46069ca6a
Duplicate keys: 0
SUCCESS - all records are in order
swathi@swathi-HP-EliteBook-8470p:~/Downloads/gensort-linux-1.5/32$ ./valsrt /home/swathi/Desktop/spark_last_part_to_run_valsrt
Records: 10
Checksum: 5015bbe53
Duplicate keys: 0
SUCCESS - all records are in order
swathi@swathi-HP-EliteBook-8470p:~/Downloads/gensort-linux-1.5/32$
```

## 16 node Cluster:

1 GB

swathi@swathi-HP-EliteBook-8470p: ~/Desktop



```
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-50-6.ec2.internal:392  
24  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-60-146.ec2.internal:5  
5581  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-61-76.ec2.internal:37  
518  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-51-70.ec2.internal:37037 (size: 8.4 KB, free: 1  
9.0 GB)  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-53-189.ec2.internal:5  
2360  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-59-221.ec2.internal:3  
7334  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-59-183.ec2.internal:5  
4769  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-61-181.ec2.internal:3  
4544  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-59-245.ec2.internal:6  
0284  
16/03/19 18:11:56 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-51-70.ec2.internal:50  
332  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-57-117.ec2.internal:59334 (size: 8.4 KB, free:  
19.0 GB)  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-51-228.ec2.internal:34187 (size: 8.4 KB, free:  
19.0 GB)  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-56-129.ec2.internal:32875 (size: 8.4 KB, free:  
19.0 GB)  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-50-205.ec2.internal:51339 (size: 8.4 KB, free:  
19.0 GB)  
16/03/19 18:11:56 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-58-70.ec2.internal:57939 (size: 8.4 KB, free: 1  
9.0 GB)  
16/03/19 18:11:57 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-57-117.ec2.internal:5  
0983  
16/03/19 18:11:57 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-51-228.ec2.internal:4  
8952  
16/03/19 18:11:57 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-56-129.ec2.internal:3  
6953  
16/03/19 18:11:57 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-50-205.ec2.internal:4  
0950  
16/03/19 18:11:57 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-58-70.ec2.internal:44  
350
```

```
ubuntu@ip-172-31-6-62: ~/spark-1.6.0-bin-hadoop2.6
filter: Unit = ()  

scala> val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().take(1000000000).drop(9999999989).foreach(println)
<console>:1: error: integer number too large
      val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().take(1000000000).drop(9999999989).foreach(println)  

scala> val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().take(10).foreach(println)
[Stage 25:=====] (28 + 2) / 30 [16/03/18 22:26:14] ERROR Executor: Managed memory leak detected;
size = 182522062 bytes, TID = 501
( "Olufe, 000000000000000000000000000000001228D4 7777888800002224444DDDDDDDEEEE00000000CCCC7777DDDD)
( .K4a-:v, 00000000000000000000000000000000188132 5555EEE888899994444FFF11111CCCCEE1111EEE6666FFFF)
( .FuD\ju, 00000000000000000000000000000000797631 5555DDDDBBBBB00000777222211112224444DDDDDD99996666)
( ;5Ythct, 000000000000000000000000000000007D3F5 2222AAAACCCCFFFFAAA44445555EEE44442222DD099992222)
( =2G^9[-, 000000000000000000000000000000000809EE 5555DDDD11111CCC9999BBBBB0000BBBCCCCFFFFCCCC44443333)
( N|M9?Sp, 00000000000000000000000000000000429597 5555FFFF000007775555999911111CCC66669999AAAAEEE8888)
( P0X2Rs&, 0000000000000000000000000000000041162E 888833339999FFF11111CCC8888CCCC9999EEEEDDD00003333)
( [Xq]\$,%, 00000000000000000000000000000000097A5F0 66666666EEEEDDD7777FFF00005555FFFFFFFFFF88885551111)
( rAnQg4v, 0000000000000000000000000000000008180D3 BBBB111111119999FFFCCCCFFFF4444BBBB88884444CCCC)
( !!)&jf3;,, 000000000000000000000000000000004602E1 4444FFFFCCCC88888888CCCCFFFFCCCC5555666666666666)
filter: Unit = ()  

scala> val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().saveAsTextFile("/mnt/raid/sparkout.txt")
filter: Unit = ()  

scala> val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().saveAsTextFile("/mnt/raid/sparkoutput")
filter: Unit = ()  

scala> :paste
// Entering paste mode (ctrl-D to finish)  

val file = sc.textFile("/mnt/raid/dataset_gb")
val filter = file.map(line => (line.substring(0,10),line.substring(10,line.length()))).sortByKey().take(10)
// Exiting paste mode, now interpreting.  

[Stage 34:=====] (8 + 4) / 30
```

```
swathi@swathi-HP-EliteBook-8470p: ~/Desktop 1:12 PM 15 Mar 2019

16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 12.0 in stage 2.0 (TID 28) in 8618 ms on ip-172-31-57-195.ec2.internal (9/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 6.0 in stage 2.0 (TID 22) in 8623 ms on ip-172-31-59-221.ec2.internal (10/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 8.0 in stage 2.0 (TID 24) in 8622 ms on ip-172-31-61-76.ec2.internal (11/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 28.0 in stage 2.0 (TID 44) in 8641 ms on ip-172-31-57-195.ec2.internal (12/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 22.0 in stage 2.0 (TID 38) in 8947 ms on ip-172-31-59-221.ec2.internal (14/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 14.0 in stage 2.0 (TID 30) in 8952 ms on ip-172-31-59-245.ec2.internal (16/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 4.0 in stage 2.0 (TID 20) in 8963 ms on ip-172-31-62-189.ec2.internal (17/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 19.0 in stage 2.0 (TID 35) in 8956 ms on ip-172-31-50-6.ec2.internal (18/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 18.0 in stage 2.0 (TID 34) in 8956 ms on ip-172-31-60-146.ec2.internal (19/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 10.0 in stage 2.0 (TID 26) in 8962 ms on ip-172-31-59-183.ec2.internal (20/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 0.0 in stage 2.0 (TID 16) in 8969 ms on ip-172-31-61-181.ec2.internal (21/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 27.0 in stage 2.0 (TID 43) in 8953 ms on ip-172-31-57-117.ec2.internal (22/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 25.0 in stage 2.0 (TID 41) in 8956 ms on ip-172-31-56-129.ec2.internal (23/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 29.0 in stage 2.0 (TID 45) in 8970 ms on ip-172-31-51-228.ec2.internal (24/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 5.0 in stage 2.0 (TID 21) in 8987 ms on ip-172-31-53-189.ec2.internal (25/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 1.0 in stage 2.0 (TID 17) in 8998 ms on ip-172-31-58-70.ec2.internal (26/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 7.0 in stage 2.0 (TID 23) in 8997 ms on ip-172-31-50-205.ec2.internal (27/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 26.0 in stage 2.0 (TID 42) in 8987 ms on ip-172-31-59-183.ec2.internal (28/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 35.0 in stage 2.0 (TID 51) in 8983 ms on ip-172-31-50-6.ec2.internal (29/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 2.0 in stage 2.0 (TID 18) in 9004 ms on ip-172-31-60-146.ec2.internal (30/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 34.0 in stage 2.0 (TID 56) in 8985 ms on ip-172-31-60-146.ec2.internal (31/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 16.0 in stage 2.0 (TID 32) in 8997 ms on ip-172-31-61-181.ec2.internal (32/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 32.0 in stage 2.0 (TID 48) in 8987 ms on ip-172-31-61-181.ec2.internal (33/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 11.0 in stage 2.0 (TID 27) in 9002 ms on ip-172-31-57-117.ec2.internal (34/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 9.0 in stage 2.0 (TID 25) in 9003 ms on ip-172-31-56-129.ec2.internal (35/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 13.0 in stage 2.0 (TID 29) in 9014 ms on ip-172-31-51-228.ec2.internal (36/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 17.0 in stage 2.0 (TID 33) in 9022 ms on ip-172-31-58-70.ec2.internal (37/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 33.0 in stage 2.0 (TID 49) in 9012 ms on ip-172-31-58-70.ec2.internal (38/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 39.0 in stage 2.0 (TID 55) in 9012 ms on ip-172-31-50-205.ec2.internal (39/40)
16/03/19 18:12:05 INFO scheduler.TaskSetManager: Finished task 23.0 in stage 2.0 (TID 39) in 9023 ms on ip-172-31-50-205.ec2.internal (40/40)
16/03/19 18:12:05 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:23) finished in 9.037 s
16/03/19 18:12:05 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
16/03/19 18:12:05 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextFile at <console>:23, took 13.743946 s
startTime: Long = 3501165834980
file: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[1] at textFile at <console>:22
filter: Unit =
duration_taken: Long = 16392549009
scala>
```

# 100 GB

```
swathi@swathi-HP-EliteBook-8470p: ~/Desktop
)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 172.0 in stage 0.0 (TID 179, ip-172-31-45-165.ec2.internal, partition 172,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 145.0 in stage 0.0 (TID 145) in 1523 ms on ip-172-31-45-165.ec2.internal (148/745)
)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 179.0 in stage 0.0 (TID 180, ip-172-31-42-81.ec2.internal, partition 179,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 136.0 in stage 0.0 (TID 148) in 1498 ms on ip-172-31-42-81.ec2.internal (149/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 181.0 in stage 0.0 (TID 181, ip-172-31-46-63.ec2.internal, partition 181,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 147.0 in stage 0.0 (TID 150) in 1431 ms on ip-172-31-46-63.ec2.internal (150/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 187.0 in stage 0.0 (TID 182, ip-172-31-42-81.ec2.internal, partition 187,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 154.0 in stage 0.0 (TID 149) in 1498 ms on ip-172-31-42-81.ec2.internal (151/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 188.0 in stage 0.0 (TID 183, ip-172-31-46-63.ec2.internal, partition 188,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 151.0 in stage 0.0 (TID 151) in 1448 ms on ip-172-31-46-63.ec2.internal (152/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 173.0 in stage 0.0 (TID 184, ip-172-31-33-86.ec2.internal, partition 173,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 157.0 in stage 0.0 (TID 152) in 1440 ms on ip-172-31-33-86.ec2.internal (153/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 180.0 in stage 0.0 (TID 185, ip-172-31-39-71.ec2.internal, partition 180,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 152.0 in stage 0.0 (TID 153) in 1455 ms on ip-172-31-39-71.ec2.internal (154/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 183.0 in stage 0.0 (TID 186, ip-172-31-47-96.ec2.internal, partition 183,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 144.0 in stage 0.0 (TID 154) in 1474 ms on ip-172-31-47-96.ec2.internal (155/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 192.0 in stage 0.0 (TID 187, ip-172-31-47-96.ec2.internal, partition 192,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 153.0 in stage 0.0 (TID 156) in 1415 ms on ip-172-31-47-96.ec2.internal (156/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 182.0 in stage 0.0 (TID 188, ip-172-31-33-86.ec2.internal, partition 182,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 162.0 in stage 0.0 (TID 155) in 1477 ms on ip-172-31-33-86.ec2.internal (157/745)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 194.0 in stage 0.0 (TID 189, ip-172-31-39-199.ec2.internal, partition 194,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 170.0 in stage 0.0 (TID 157) in 1459 ms on ip-172-31-39-199.ec2.internal (158/745)
)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Starting task 197.0 in stage 0.0 (TID 190, ip-172-31-39-199.ec2.internal, partition 197,NODE_LOCAL, 2168 bytes)
16/03/26 16:33:51 INFO scheduler.TaskSetManager: Finished task 175.0 in stage 0.0 (TID 158) in 1460 ms on ip-172-31-39-199.ec2.internal (159/745)
```

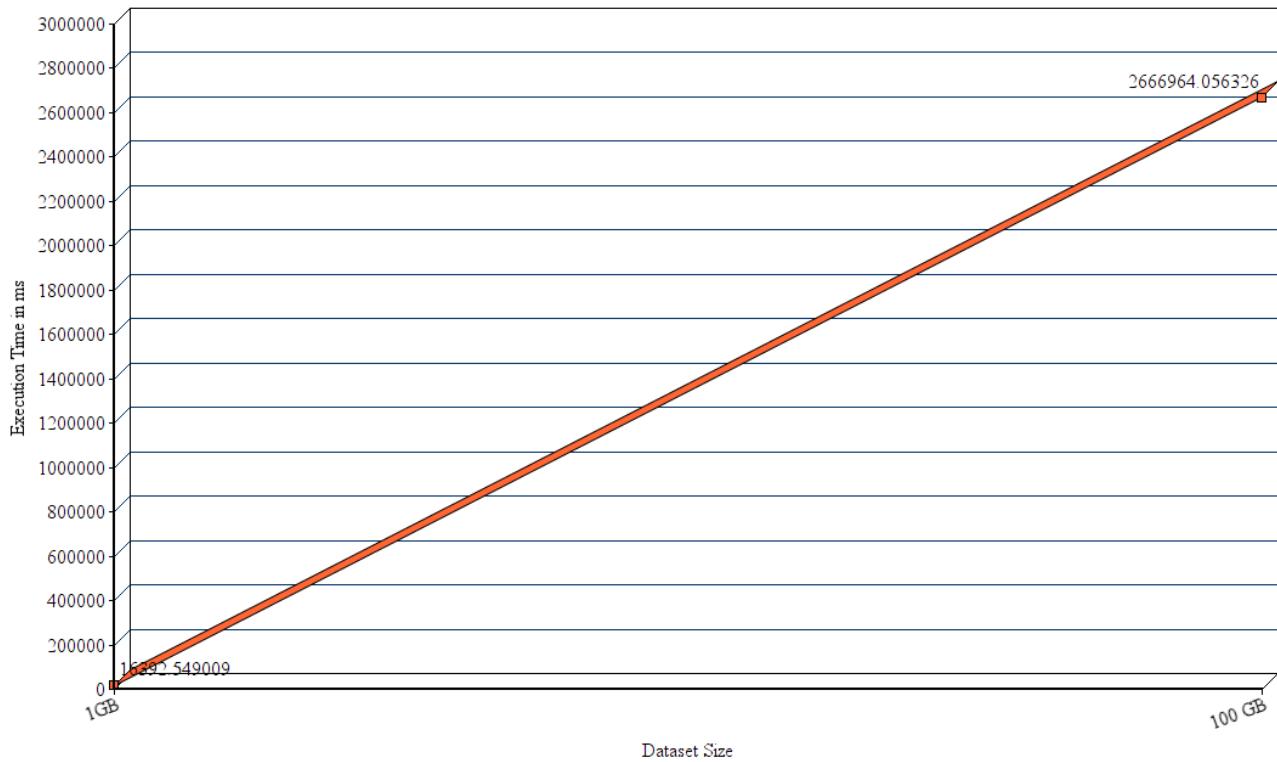
```
swathi@swathi-HP-EliteBook-8470p: ~/Desktop
,
, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 77.0 in stage 1.0 (TID 796, ip-172-31-42-81.ec2.internal, partition 77,NODE_LOCAL, 2157 bytes)
,
, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 8.0 in stage 1.0 (TID 755) in 6386 ms on ip-172-31-42-81.ec2.internal (20/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 61.0 in stage 1.0 (TID 797, ip-172-31-41-24.ec2.internal, partition 61,NODE_LOCAL, 2157 bytes)
,
, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 20.0 in stage 1.0 (TID 759) in 6405 ms on ip-172-31-41-24.ec2.internal (21/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 11.0 in stage 1.0 (TID 756) in 6410 ms on ip-172-31-42-162.ec2.internal (22/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 35.0 in stage 1.0 (TID 798, ip-172-31-42-162.ec2.internal, partition 35,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 30.0 in stage 1.0 (TID 772) in 6407 ms on ip-172-31-42-162.ec2.internal (23/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 58.0 in stage 1.0 (TID 799, ip-172-31-42-162.ec2.internal, partition 58,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 50.0 in stage 1.0 (TID 800, ip-172-31-39-156.ec2.internal, partition 50,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 16.0 in stage 1.0 (TID 757) in 6424 ms on ip-172-31-39-156.ec2.internal (24/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 33.0 in stage 1.0 (TID 801, ip-172-31-40-12.ec2.internal, partition 33,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 3.0 in stage 1.0 (TID 751) in 6433 ms on ip-172-31-40-12.ec2.internal (25/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 48.0 in stage 1.0 (TID 802, ip-172-31-40-12.ec2.internal, partition 48,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 29.0 in stage 1.0 (TID 767) in 6432 ms on ip-172-31-40-12.ec2.internal (26/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 60.0 in stage 1.0 (TID 803, ip-172-31-47-96.ec2.internal, partition 60,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 5.0 in stage 1.0 (TID 752) in 6509 ms on ip-172-31-47-96.ec2.internal (27/745)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Starting task 63.0 in stage 1.0 (TID 804, ip-172-31-47-96.ec2.internal, partition 63,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:24 INFO scheduler.TaskSetManager: Finished task 23.0 in stage 1.0 (TID 768) in 6504 ms on ip-172-31-47-96.ec2.internal (28/745)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Starting task 55.0 in stage 1.0 (TID 805, ip-172-31-46-63.ec2.internal, partition 55,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Finished task 12.0 in stage 1.0 (TID 764) in 6853 ms on ip-172-31-46-63.ec2.internal (29/745)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Starting task 67.0 in stage 1.0 (TID 806, ip-172-31-46-63.ec2.internal, partition 67,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Finished task 4.0 in stage 1.0 (TID 748) in 6860 ms on ip-172-31-46-63.ec2.internal (30/745)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Starting task 45.0 in stage 1.0 (TID 807, ip-172-31-39-199.ec2.internal, partition 45,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Finished task 17.0 in stage 1.0 (TID 770) in 7058 ms on ip-172-31-39-199.ec2.internal (31/745)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Starting task 57.0 in stage 1.0 (TID 808, ip-172-31-39-199.ec2.internal, partition 57,NODE_LOCAL, 2157 bytes)
16/03/26 16:34:25 INFO scheduler.TaskSetManager: Finished task 6.0 in stage 1.0 (TID 754) in 7066 ms on ip-172-31-39-199.ec2.internal (32/745)
```

```
swathi@swathi-HP-EliteBook-8470p: ~/Desktop
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-5-6.ec2.internal:33605 in memory (size: 2.0 KB, free: 1
536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-12-131.ec2.internal:56233 in memory (size: 2.0 KB, free:
: 1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-6-209.ec2.internal:38295 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-15-81.ec2.internal:56038 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-8-199.ec2.internal:34288 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-1-170.ec2.internal:40710 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-4-82.ec2.internal:43139 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-4-9.ec2.internal:54367 in memory (size: 2.0 KB, free: 1
536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-8-194.ec2.internal:36204 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:24 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-0-118.ec2.internal:35432 in memory (size: 2.0 KB, free:
1536.7 MB)
16/03/27 03:06:28 INFO storage.BlockManagerInfo: Removed broadcast_1_piece0 on ip-172-31-12-116.ec2.internal:38372 in memory (size: 2.0 KB, free
: 1536.7 MB)
16/03/27 03:06:28 INFO spark.ContextCleaner: Cleaned accumulator 1
16/03/27 03:06:51 INFO scheduler.TaskSetManager: Finished task 26.0 in stage 2.0 (TID 1516) in 1548279 ms on ip-172-31-0-118.ec2.internal (26/30
)
16/03/27 03:17:12 INFO scheduler.TaskSetManager: Finished task 3.0 in stage 2.0 (TID 1493) in 2169109 ms on ip-172-31-12-116.ec2.internal (27/30
)
16/03/27 03:17:39 INFO scheduler.TaskSetManager: Finished task 19.0 in stage 2.0 (TID 1509) in 2195571 ms on ip-172-31-12-116.ec2.internal (28/3
0)
16/03/27 03:21:16 INFO scheduler.TaskSetManager: Finished task 13.0 in stage 2.0 (TID 1503) in 2412415 ms on ip-172-31-6-77.ec2.internal (29/30)
16/03/27 03:21:36 INFO scheduler.TaskSetManager: Finished task 29.0 in stage 2.0 (TID 1519) in 2433208 ms on ip-172-31-6-77.ec2.internal (30/30)
16/03/27 03:21:36 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:23) finished in 2433.217 s
16/03/27 03:21:36 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
16/03/27 03:21:36 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextfile at <console>:23, took 2564.273609 s
startTime: Long = 6755638958376
file: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[1] at textFile at <console>:22
filter: Unit = ()
duration taken: Long = 2666964056326
scala> [Trash]
```

```
spark master
Installing : dos2unix-3.1-37.5.amzn1.x86_64
Verifying  : dos2unix-3.1-37.5.amzn1.x86_64
1/1
1/1
Installed:
dos2unix.x86_64 0:3.1-37.5.amzn1
Complete!
root@ip-172-31-59-80 64]$ dos2unix /home/ec2-user/16_node_spark_output_partone
dos2unix: converting file /home/ec2-user/16_node_spark_output_partone to UNIX format ...
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_node_spark_output_partone
sump pump fatal error: pfunc_get_rec: partial record of 91 bytes found at end of input
root@ip-172-31-59-80 64]$ unix2dos /home/ec2-user/16_node_spark_output_partone
unix2dos: converting file /home/ec2-user/16_node_spark_output_partone to DOS format ...
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_node_spark_output_partone
sump pump fatal error: pfunc_get_rec: partial record of 2 bytes found at end of input
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_node_spark_output_partone
sump pump fatal error: pfunc_get_rec: partial record of 2 bytes found at end of input
root@ip-172-31-59-80 64]$ unix2dos /home/ec2-user/16_node_spark_output_partone
unix2dos: converting file /home/ec2-user/16_node_spark_output_partone to DOS format ...
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_node_spark_output_partone
sump pump fatal error: pfunc_get_rec: partial record of 2 bytes found at end of input
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_nodes_spark_output_lastpart
Records: 10
Checksum: 43544f077
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-59-80 64]$ unix2dos /home/ec2-user/16_node_spark_output_partone
unix2dos: converting file /home/ec2-user/16_node_spark_output_partone to DOS format ...
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_nodes_spark_output_lastpart
Records: 10
Checksum: 43544f077
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-59-80 64]$ unix2dos /home/ec2-user/16_node_spark_output_partone
unix2dos: converting file /home/ec2-user/16_node_spark_output_partone to DOS format ...
root@ip-172-31-59-80 64]$ ./valsort /home/ec2-user/16_node_spark_output_partone
Records: 10
Checksum: 4323a51e3
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-59-80 64]$
```

## Performance: Execution Time (ms)

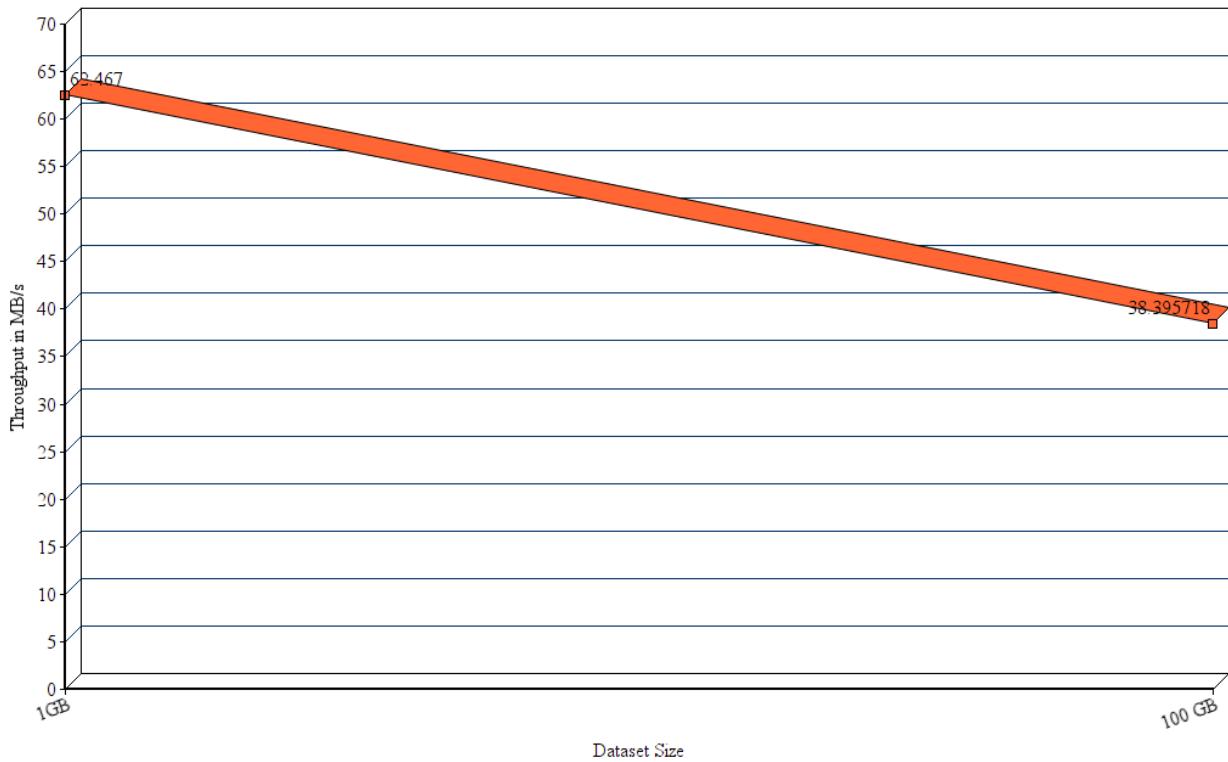
Spark 16 Node Cluster



There is a linear increase in the execution time for increase in dataset size.

## Throughput in MB/s:

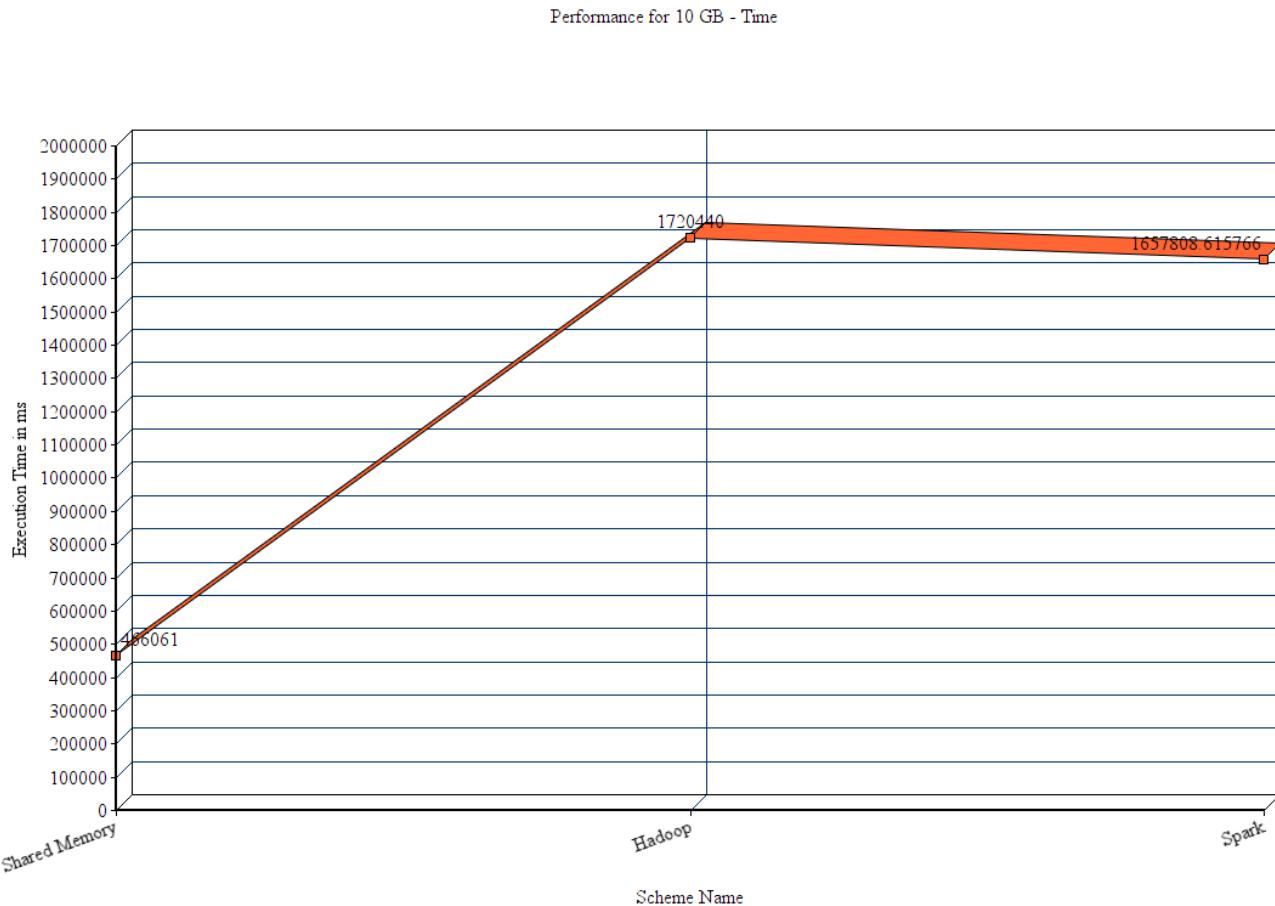
Spark 16 Node Cluster



There is a drop in the throughput due to time taken for execution.

## **COMPARISON OF SHARED MEMORY, HADOOP AND SPARK for 10 GB dataset single node:**

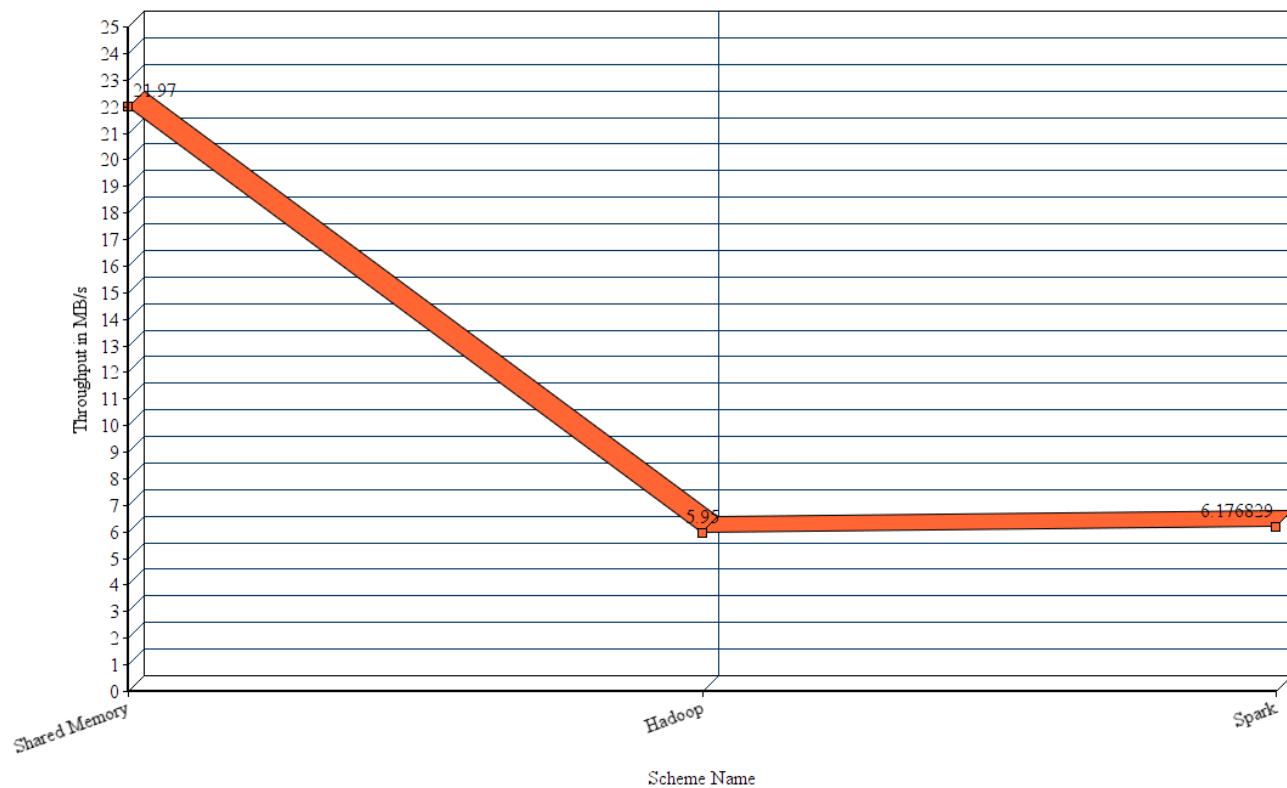
**Execution Time in ms:**



In the comparison of shared memory, hadoop and spark, since the dataset size is small, the performance for Hadoop and Spark is almost same.

## Throughput in MB/s:

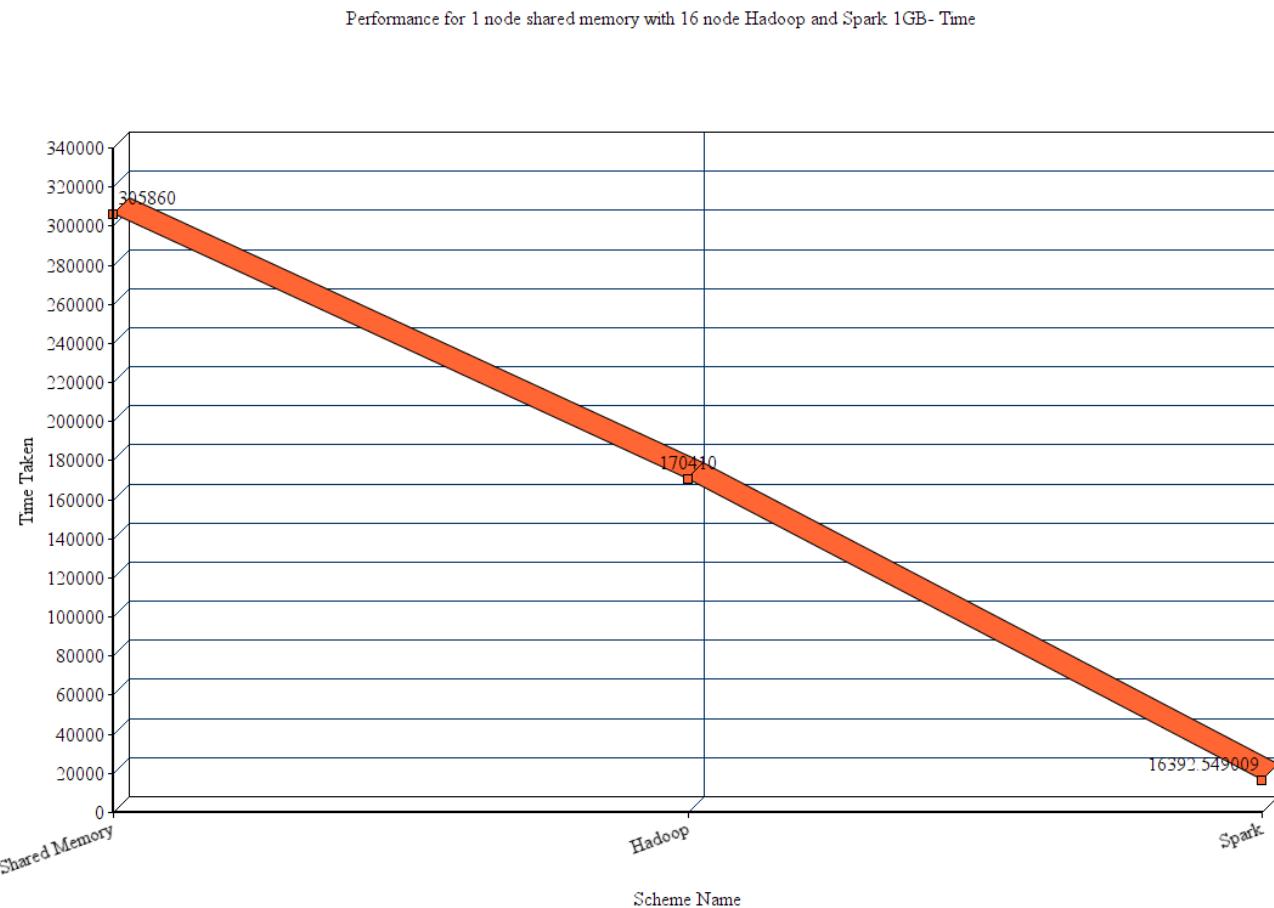
Performance for 10 GB - Throughput



The throughput is almost similar for Hadoop and Spark and is high for shared memory due to the lesser execution time. The shared memory does not store intermediate data during the runs. This is also efficient given that the dataset size is comparatively small.

## COMPARISON OF 1 NODE SHARED MEMORY WITH 16 NODE CLUSTER OF HADOOP AND SPARK :

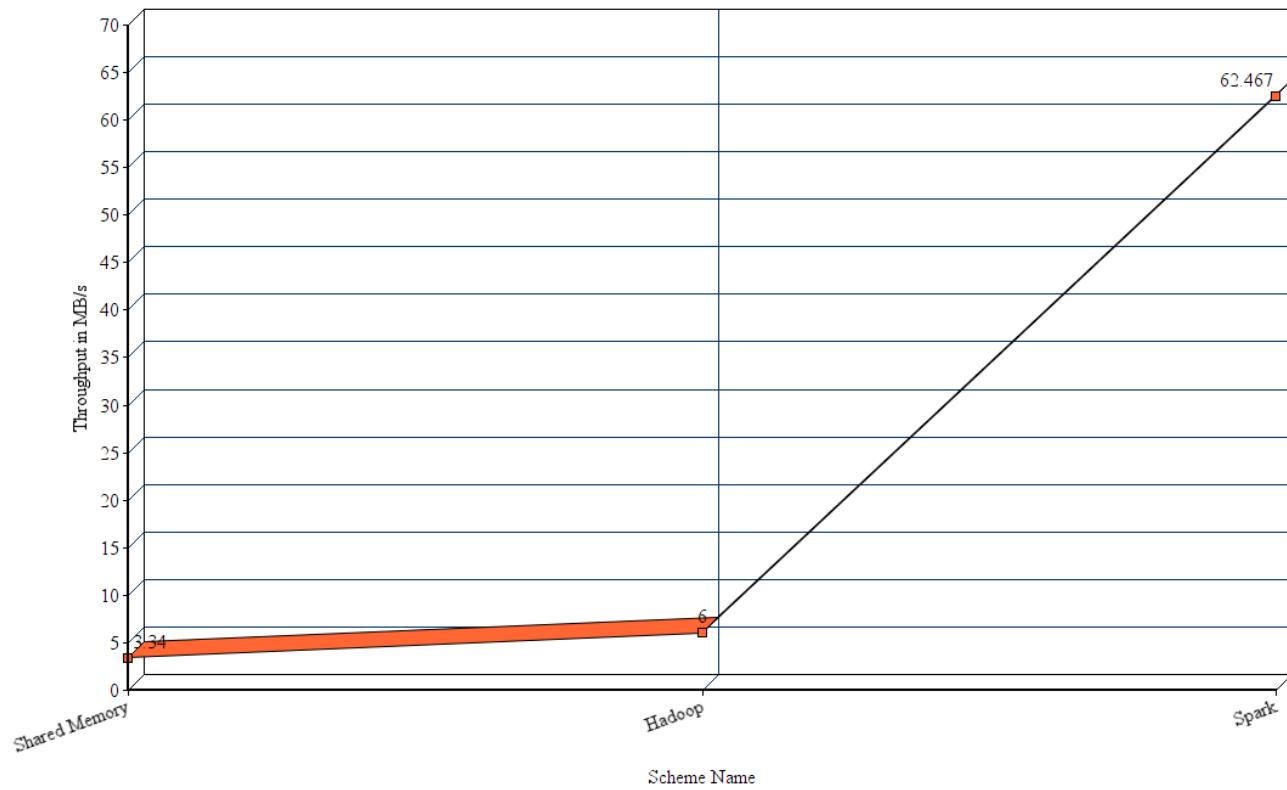
Execution Time in ms:



When compared with 16 node cluster, SPARK is the most efficient of the three as it saves shuffle data and leads to faster runs.

## Throughput in MB/s:

Performance for 1 node shared memory with 16 node Hadoop and Spark 1GB- Time

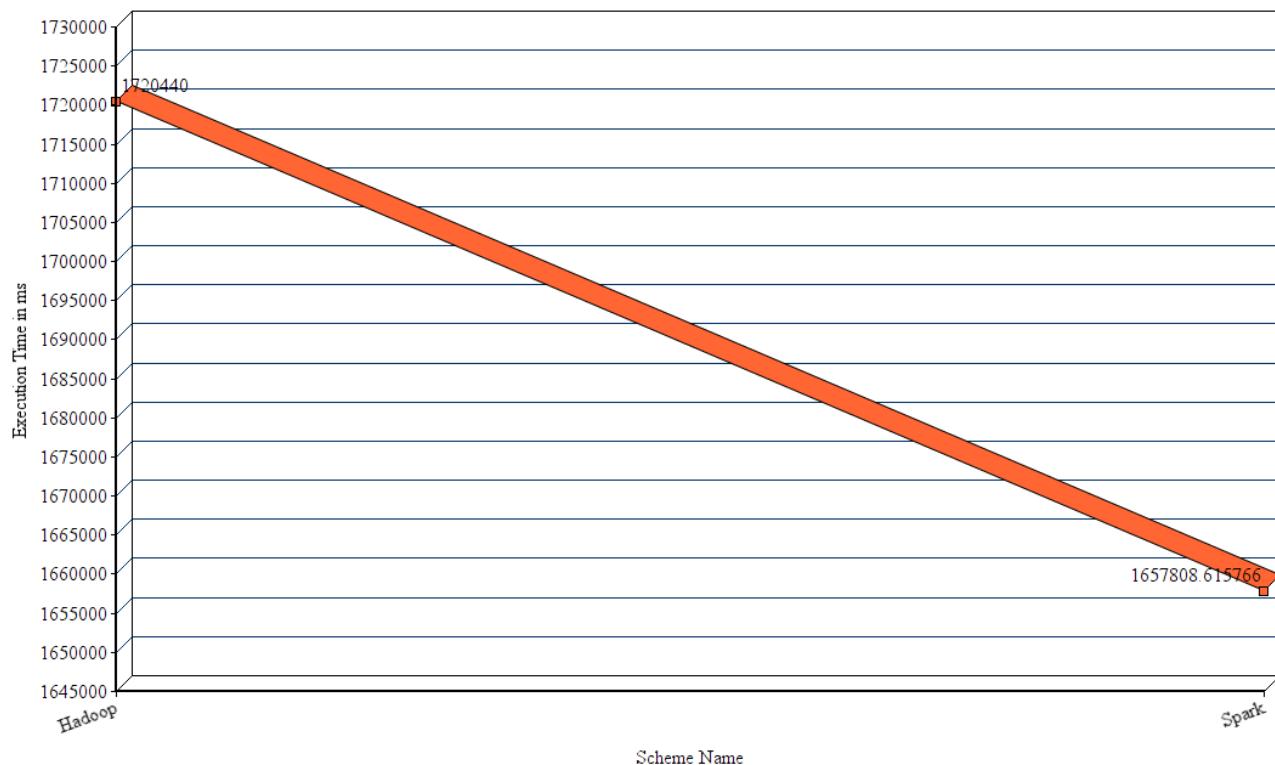


Spark gives the highest throughput as it has the least execution time.

## COMPARISON OF HADOOP AND SPARK ON SINGLE NODE:

### Execution Time in ms:

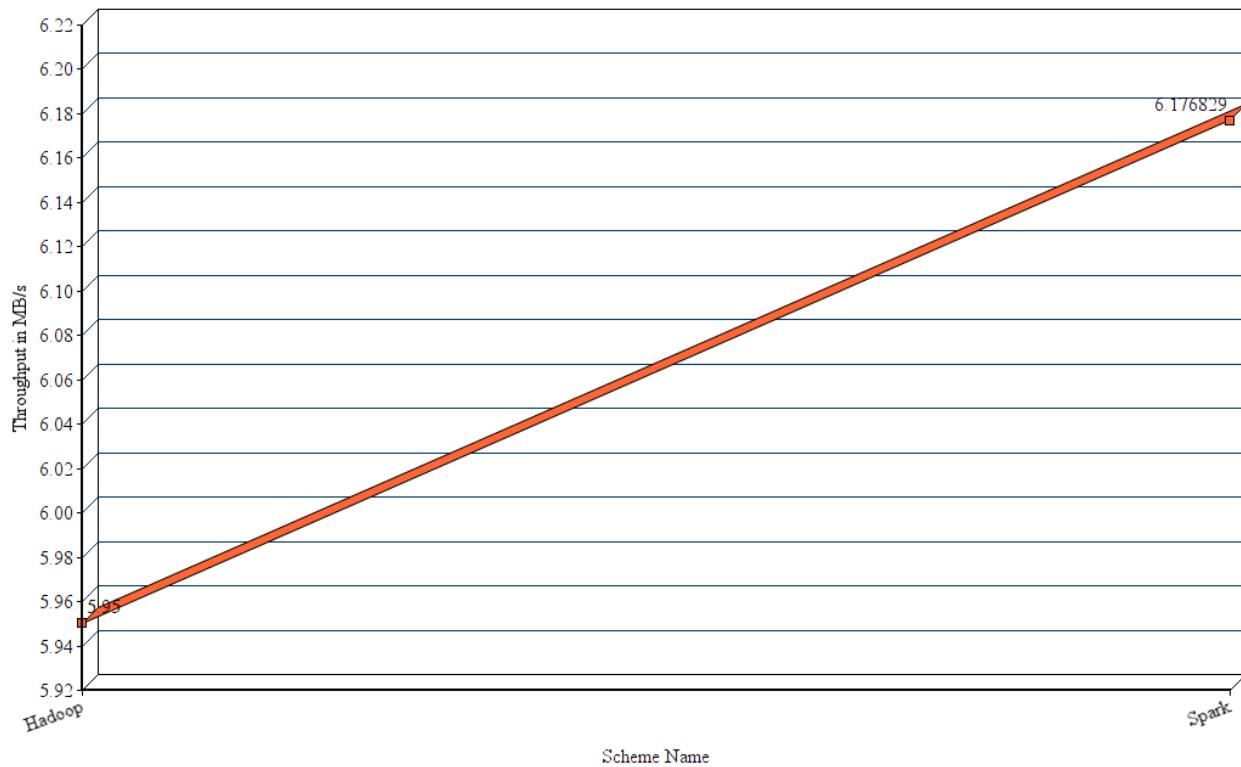
Hadoop and Spark Comparison for Single Node 10 GB



Spark has lesser execution time as compared to Hadoop.

## Throughput in MB/s:

Hadoop and Spark Comparison for Single Node 10 GB

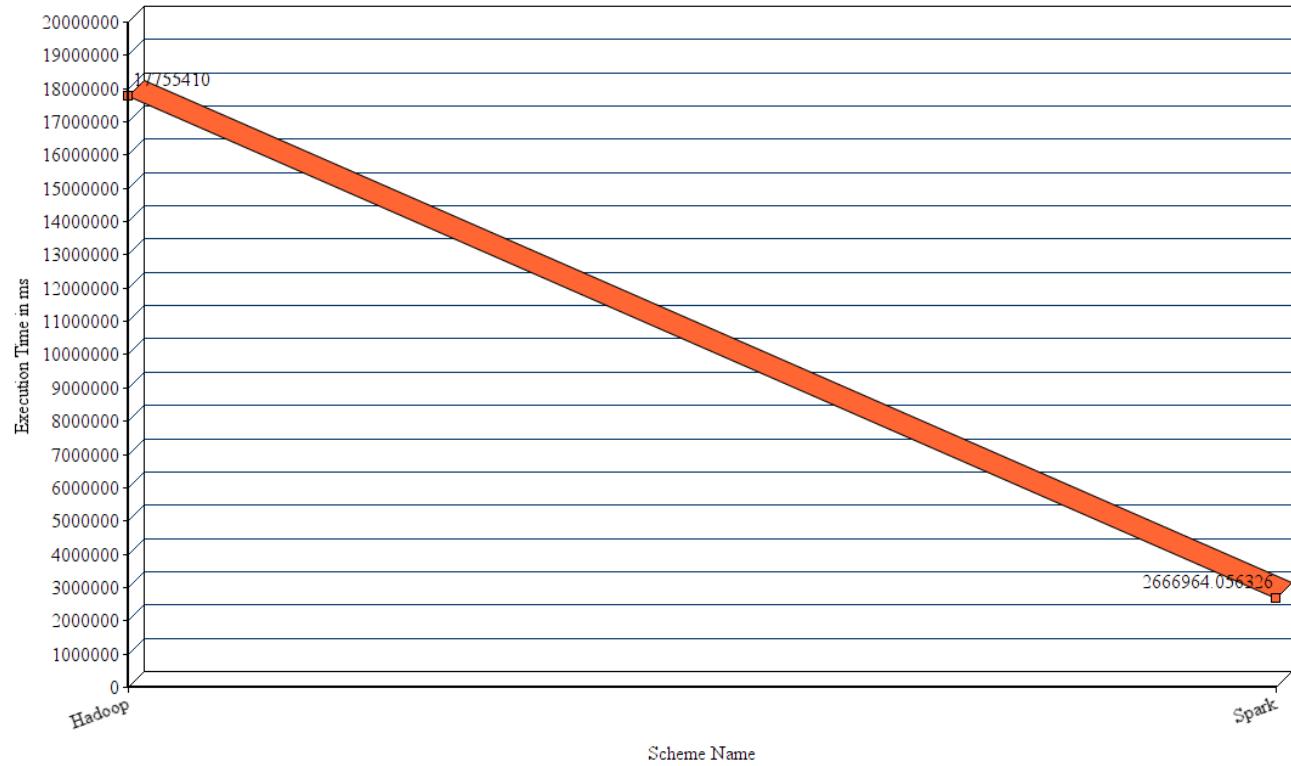


Due to lesser execution time, the throughput for Spark is higher compared to Hadoop

## COMPARISON OF HADOOP AND SPARK ON 16 NODE CLUSTER 100 GB:

### Execution Time in ms:

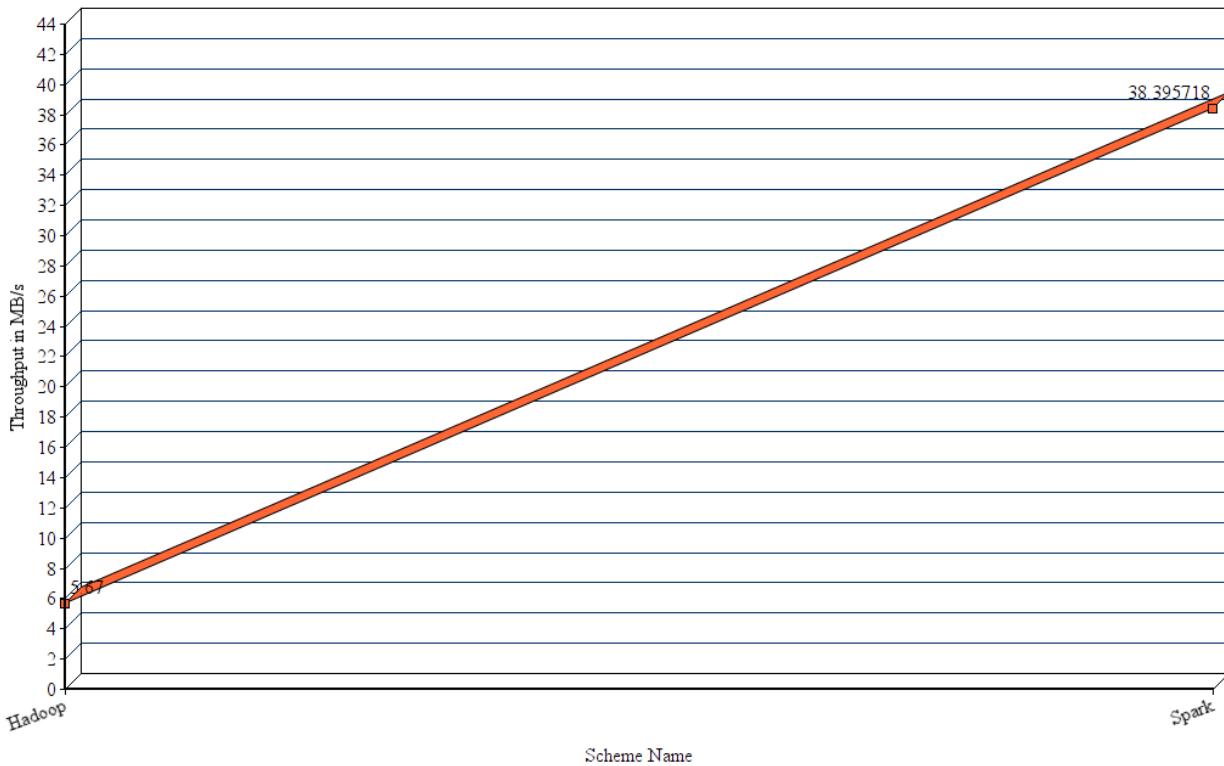
Hadoop and Spark Comparison for 16 Node Cluster 100 GB



The same trend as for single node appears in case of 16 node cluster.

## Throughput in MB/s:

Hadoop and Spark Comparison for 16 Node Cluster 100 GB



Due to lesser execution time Spark has higher throughput than Hadoop.

- 1) For one node scale, Shared memory gives the best performance as the data is accessed from disk and does not have to bear the overhead of being stored on a distributed file and being distributed across different slave nodes.
- 2) For 16 node scale, Spark gives the best performance as it saves the intermediate shuffle information which will be used by the further runs.
- 3) The same goes for 100 and 1000 node scale. Spark would give the best performance.
- 4) In 2014 and 2013, the winners who used Spark got a throughput of the order of 70,000 MB/s and Hadoop was about 23,000 MB/s. This is very high compared to the ones obtained in the c3.large instance due to constraints on resources such as processor and memory available for the computation.
- 5) CloudSort – It is a scheme to estimate the most efficiently the parameters for cost required to run an IO intensive computation. Resources on the cloud are used for estimation as they have same configuration and effectively estimate all the possible costs incurred in designing the infrastructure. Due to its affordability, accessibility and auditability the resources on cloud best suit this task. The cloud platform is most suitable for providing a cost effective and efficient way to analyze this metric rather than working on system where the cost maybe high and comparison may not be efficient due to hardware and other constraints.